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Plastics

EALING WITH THE MANUFACTURE, USES AND POTENTIALITIES OF PLASTIC MATERIALS

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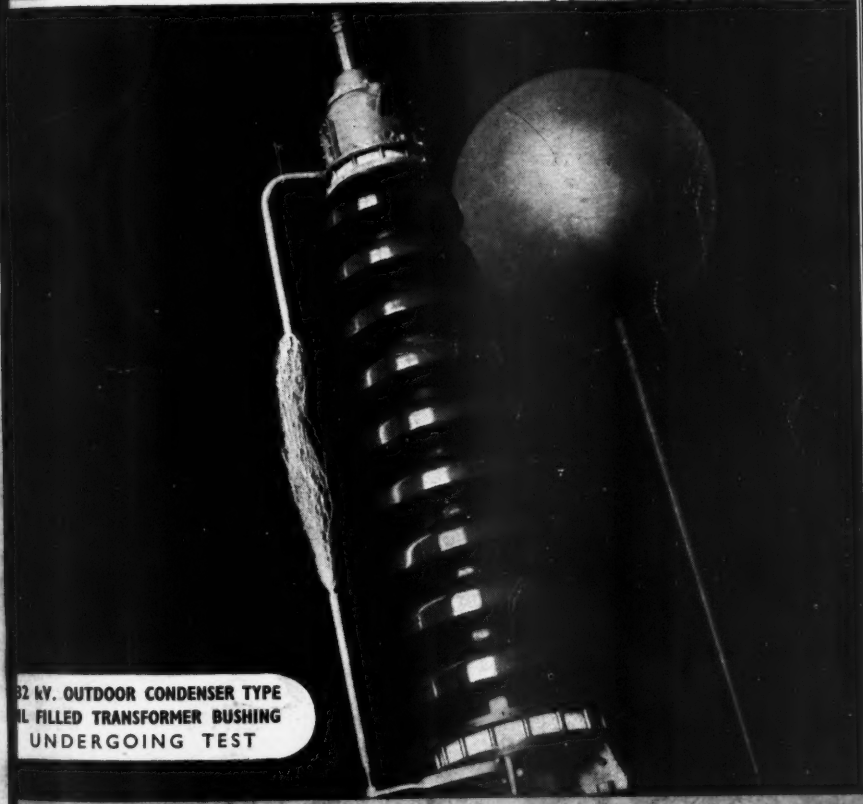

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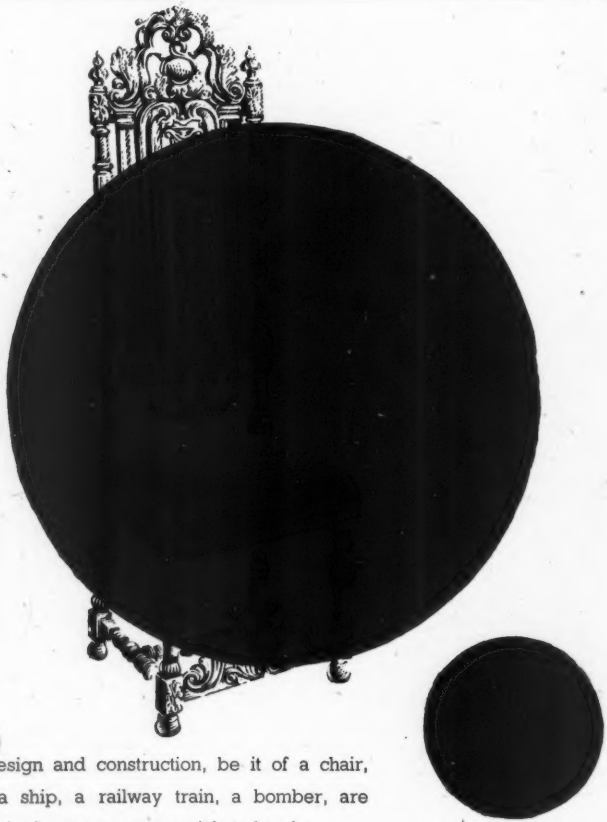

Design and construction, be it of a chair, a house, a ship, a railway train, a bomber, are dependent in degree upon materials to hand.

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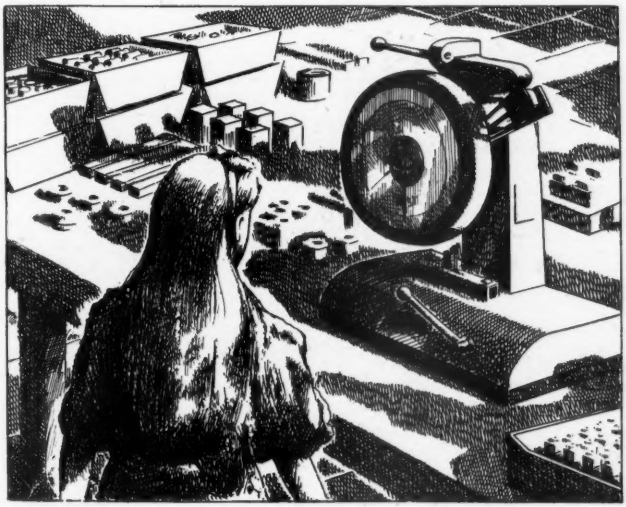
Alice in Plasticland—No. 8



Plastics can take it

"Off with his head," said the "Impact Machine." Alice pricked her ears up. She'd heard that one before. The old Queen was always saying it when she got into a bad temper.

"Why off with its head?" she asked.

"That's what I'm here for," said the machine, "to test how much these plastic parts can stand up to in the way of a direct blow amidships. If they can stand up to my punches they can certainly take it," and so saying, he struck out mightily once more.

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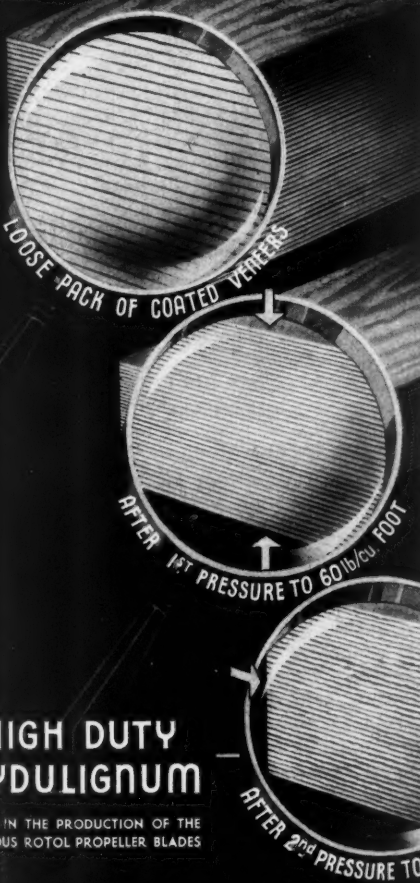

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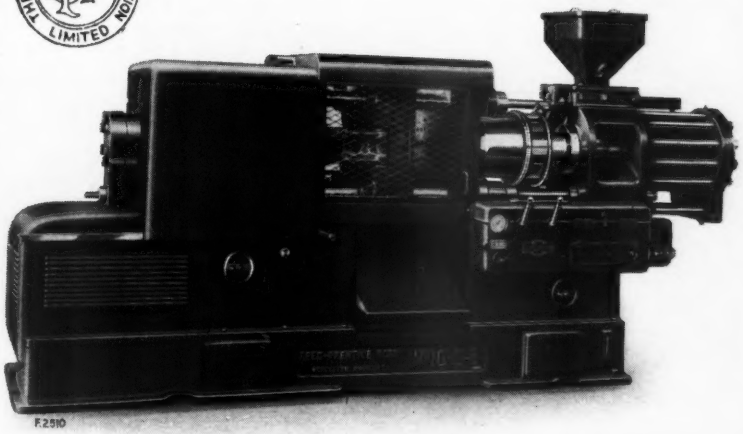

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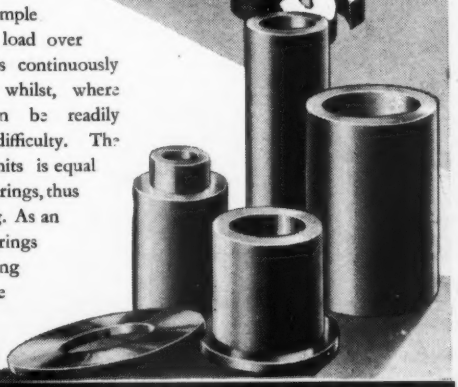

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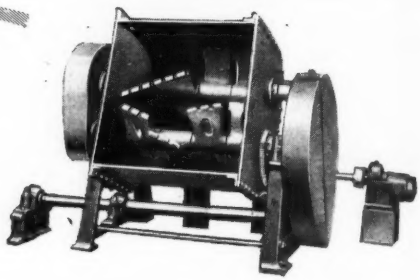

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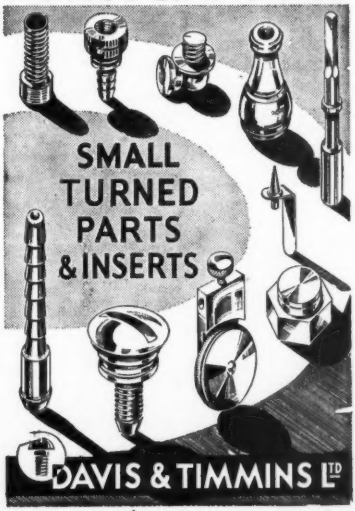

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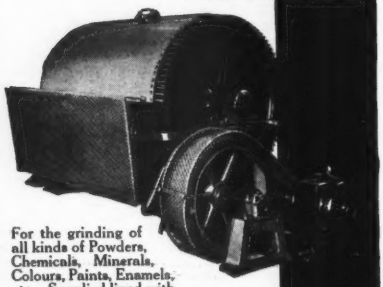

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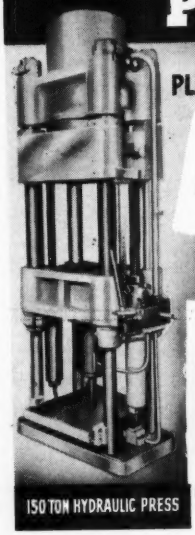

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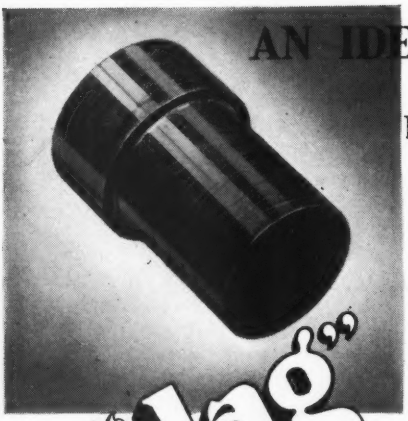

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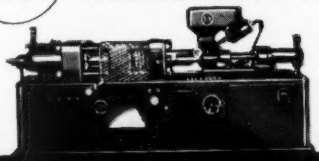

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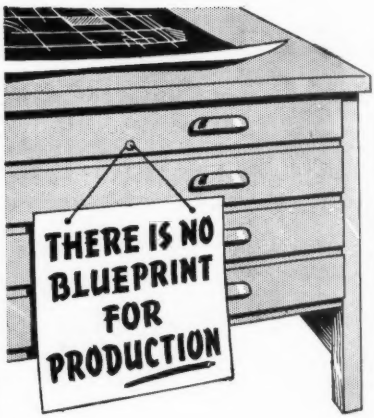

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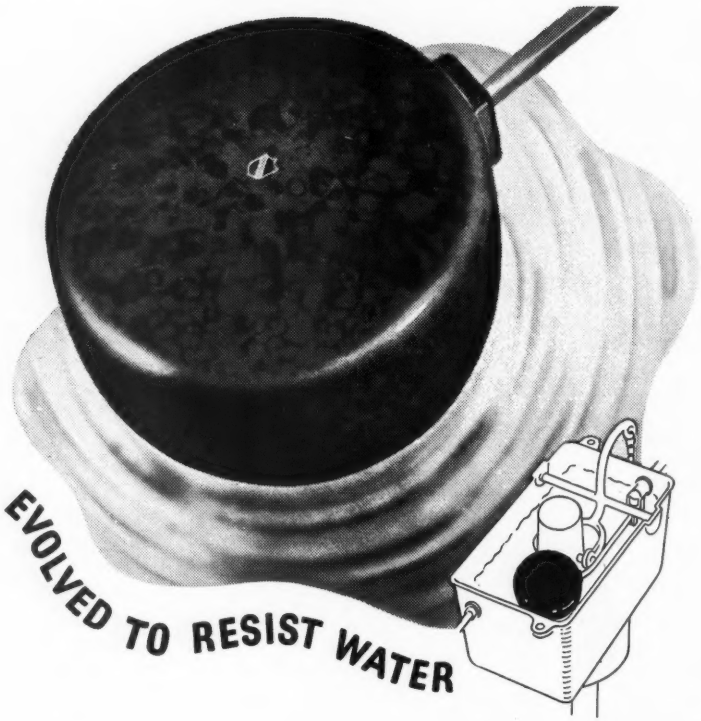

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Vol. VIII. No. 90 NOVEMBER, 1944

Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

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NOTICES

All instructions, matter and passed proofs for all kinds of advertisements must reach the Head Office of "PLASTICS" by the 24th of each month to ensure insertion in the following month's issue.

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SUBSCRIPTION — "PLASTICS" will be mailed regularly to any address in the United Kingdom or abroad for—Twelve issues for 19s., post free; pro rata for fewer numbers.

SAVE PAPER

More than ever is paper waste required for our war industries. Waste paper makes munitions in a hundred forms—from shell cases to aeroplane parts.

The fact that goods made of raw materials in short supply because of war conditions are advertised in this journal should not be taken as an indication that they are necessarily available for export.

EDITORIALS

Resin-impregnated Pulp

IT was with considerable interest that we listened to a reading of Mr. H. Carl Martin's paper, on October 26, at a meeting of the London Section of the Institute of the Plastics Industry. With the kind permission of the Papers Committee of the Institute we have pleasure in publishing it on another page. Mr. Martin was unable to read his paper owing to his departure for the U.S.A.; consequently some of the questions put to his colleague Mr. Nochar, who was present, could not be answered in their entirety. Nevertheless, it is a fascinating subject, full of promise and indicative of the interest the paper-making industry will take in the plastics industry.

Obviously Mr. Martin and the Bristol Aeroplane Co. have done a great deal of practical work on the subject and deserve much credit. Large flat sheets in size equal to ordinary laminated sheets are possible, although it was slightly disappointing to find that large mouldings are possible only with almost the same difficulties that attend ordinary compression moulding, since the pressures Mr. Martin employs for moulding his preforms (about 1,000 lb. per sq. in.) are not what we term low pressures. However, we learnt much on the reactivity of phenolic resins and paper pulp and we shall learn more with time.

There was, we consider, some rather ill-timed criticism of the paper. Dr. Haefely, for example, remarked that the fundamentals of pulp-treatment with resins in the beater is not new and pointed out that Panilax, which has been on the market for some years, is of that type. All of which is perfectly true, but how many know it?

We dare swear that few of the listeners in the lecture room knew that Panilax (the well-known aniline-formaldehyde resin) was produced in such a manner and fewer still of the plastics public knew what a paper beater looks like. We have good reason to know that Micanite and Insulators, Ltd. (of which company Dr. Haefely is a distinguished member), has not yet considered it feasible to publish details of the beater method employed in Panilax production in the way Mr. Martin has done.

No doubt history could go back many years to delve into the origins of the process, but we are still grateful to Mr. Martin (and to the Institute for arranging the reading) for an exposition of what may prove a valuable addition to the plastics industry.

Nature's Kaleidoscope

MANY months ago we laid stress on the diminishing petroleum reserves of the world, and that our main effort for the future welfare of our industry and, indeed, of the country should be directed to manufacturing what we require from our huge coal resources. Nevertheless, we urged that real refineries—that is, those producing chemicals and plastics from petroleum—should be created here, using imported oil, partly because of the monetary value of such an industry and partly because of the technical training to be obtained thereby.

When the news burst last month that oil had been discovered in England and was being refined here, we were justifiably jubilant. Not that the divulged annual production of 100,000 tons was much to get excited about, for in peacetime that quantity would last us about a week, but at least it might prove the beginning of more important discoveries. One reporter claimed to have counted 300 derricks "somewhere in England," so

presumably the Government is not lacking in energy in the search for more.

Even 100,000 tons a year is not to be sneezed at, and if it is economically produced the Government might be persuaded to transfer it to other hands to form the basis of a sizable chemical and plastics industry. At least, there could be no argument about high cost of transport from the Americas or from the Near East. Furthermore, 100,000 tons a year as fuel, lubricant, etc., would bring in, say, £2,000,000 to £3,000,000 only, depending on the quality of the oil. In the form of plastics or chemicals these figures would be doubled at least, besides giving employment to larger numbers.

Even more surprising news, in some ways quite unpalatable, is that recently given over the wireless by John Strachey to the effect that Germany has been working oil wells newly discovered on German territory, producing over 1,000,000 tons per annum. This is important not only for Germany's present welfare—we had fondly imagined that we had deprived her of most of her oil resources—but also for her post-war economy. It may, of course, prove that these new oil wells are close to the Polish borders, and to be a continuation of the latter country's underground resources, in which case they may pass out of Germany's ownership. If Germany retains them, then it may well be that some of her chemical industries will be re-orientated to accommodate this, for her, new raw material, for she, like Great Britain, was one of the petroleum "have nots."

The Illogic of War

THE rapidly changing shape of Nature's gifts brings to mind the arguments put forth by Squadron Leader Murray Harris (brother of "Bomber" Harris) in his recently published "The Logic of War." The subject is far from plastic manufacture, but is at least important to all industrialists, especially those engaged in chemical manufacture.

Squadron Leader Harris, in an attempt to answer the question, "What shall we do with Germany?" so that another and worse war does not break out again, begins with the probable truth that war is a matter of communications and explosives. He argues, therefore, that Germany should be deprived of the two elements that make communications and explosives possible, namely, hydrogen for making synthetic gasoline, and nitrogen for making synthetic ammonia and thence nitric acid for explosives. Of the two, hydrogen is "the master switch," as he terms it, since hydrogen is essential to both synthetic petrol and synthetic ammonia. Stop hydrogen and nitrogen production, he says, and Germany cannot make another war.

This at first sight seems extremely common sense, but how hollow is the argument when we are confronted with the news given above regarding new oil wells in Germany, which if increased would close down all synthetic plants immediately.

But there is even stronger reason for refuting these specious arguments, for they take no heed—indeed they indicate a curious ignorance—of the possible advance of science. Thus petroleum, synthetic or natural, is not the only fuel. To-day only high-grade petrol will drive our aeroplanes and cars; to-morrow it will be Diesel oil; and the day after it will be coal or wood tar or some other combustible. The day after that it may be water—that is, water can be electrolytically decomposed into hydrogen and water, and both can be exploded in a cylinder to recombine as exhaust into steam. This latter system is quite well known and has worked. And to cap it all, we may get atomic energy, and all that the German army or air force or navy need carry about with them is a few pounds of sugar or a couple of volumes of "The Logic of War" and, of course, the necessary atom-breaking apparatus, and they would be able to travel from Berlin to Kamchatka without lines of communication.

All of which makes us wonder what Squadron Leader Harris's book would have been like if it had been written in

1918. It would have contained nothing about synthetic petrol, since hydrogenation for that purpose was unknown.

We shall not find the whole solution to the problem in the hydrogen and nitrogen factories of Germany. We probably could find it only in the total control of German science.

The Face of Science

A MOST interesting type of advertisement is about to appear in the daily journals. I.C.I., Ltd., have launched a new series by means of which there will be introduced to the public a representative selection of the men and women who work in the laboratories and factories—the developers of chemical science—by means of a series of portraits drawn by well-known artists.

The series has two important aims—to give recognition to the human factor behind the machine and to afford some indication of the part each individual plays in chemical research and chemical production.

Whatever the portraits are like, it will do both these things, and I.C.I., Ltd., are to be commended for launching a very laudable project.

If we may diverge slightly from the problem of "putting across" science to the public, we may ask, "What will the portraits be like?" What, indeed, does a research chemist look like? We are willing to bet that we can take any man from the street—a bargee, a waiter, a bar-tender or a company-promoter—put him into a white coat, put in a cardboard background of a benzole fractionating column and make him look longingly and earnestly at a test-tube, and we shall get a picture of—a research chemist. At least to the satisfaction of the public.

What are we driving at? We don't quite know, except that a good many artists claim or have been accorded the ability to show the character and, even more subtly, the mind of the sitter.

There is obviously a common denominator in character and mind of all research chemists. Can the artist bring it out and show it to the public?

So far the artist has failed signally to do so. Judging from the portraits of famous chemists in the Chemical Society we cannot discern any difference between them and those in the Institute of Civil Engineers or those of the past-presidents of the Men's Hosiery and Underwear Association. They all look the same to us; the first are not in white coats and have no microscopes sticking out of their pockets, the second grip no sledge-hammers, and the third hold no yard measures in their hands.

Have the artists failed? Truly their task is difficult, for we know a brilliant physico-chemist in the infra-red field who looks and behaves like a prosperous farmer; an explosives expert who would make a fortune on the music-hall stage singing comic songs à la Harry Champion, and, yes, looks like him; and a first-class research worker in plastics with the manners of a family solicitor. We can easily understand the well-known writer who said, in 1938, that Mr. Himmler with one hand on the flaxen head of a child and the other fondling a posy of daffy-down-dillies looks the gentlest soul alive.

Artists may be able to hold up the mirror to Nature, but can they hold up the mirror to the Scientist?

PLYWOOD GLUES

A report on the weathering qualities of plywood glues has recently been prepared by Forest Products Research Laboratory. With the coming of synthetic glues, which in some forms are completely moisture- and rot-proof, the field of application has widened enormously. The object of the experiments described is to show which glues are suitable for severe services.

The long-term weathering tests show that phenolic and urea resins used neat and the urea type extended with not more than 25 per cent. flour form the more weather-resistant type of adhesives. Accelerated tests, for comparison with long-term exposure, show that only straight resins, or those containing a maximum of 50 per cent. of flour, are suitable for all weather conditions.

Machining of Plastics with Ceramic Tools

This paper, by Dr. Ing. W. Osenberg, of Dresden, has been translated for this journal by Dr. H. P. Zade, from "Maschinenbau Der Betrieb," Vol. 17, 1938, pp. 127-130.

PLASTICS have been in the focus of interest for the past few years due to the dependence on foreign currency of a number of our raw materials. It is essential to carry out research on the conserving of cutting edges, on suitable tool materials and on design of the tools, because many articles made from plastics have to be machined by some cutting process. The following paper shows a number of possibilities, not only so far as the choice of materials for tools is concerned, but also regarding their manufacture. Furthermore, a scale of merit comparing these tools with orthodox tools for the machining of plastics is provided on the basis of investigations into the life of the tools.

The Cutting of Plastics

An excessive wear of cutting edges can be observed when machining any kind of plastics, whether they be moulded or cast parts, whether artificial or natural resins, whether protein, cellulose or hydrocarbon compounds. This wear is sometimes more pronounced than the wear occurring in the machining of light metals and steel, although strength and hardness of plastics are well below those of metals. The pronounced blunting of tools can be explained on the one hand by the comparatively high content of organic fillers in plastics, on the other hand by the difference of hardness between the filler and the natural resin. The most essential factor, however, is the low heat conductivity of plastics which amounts to only approximately 1 per cent. of the heat conductivity of steel. When machining metals, for instance in the case of turning, the rotating work-piece as well as the cuttings convey heat to a large extent. When machining plastics heat is accumulated near the foremost cutting edge to a considerable extent. The resulting cutting edge temperatures cause the alloying components of tool steels to go into solution and to disintegrate. It goes without saying that this process only occurs near the foremost cutting edge and only after a continued action at higher temperatures. Even in the case of carbides stable to high temperatures, the problem of heating is predominant in spite of the high sintering temperature used for their manufacture. Blunting of these tools will be effected by the grinding action of the plastic and its filler only as a secondary consideration.

Ceramic Tools

Some materials which are used in the ceramic industry are specially suitable as tools for the machining of plastics in the cutting of which the previously men-

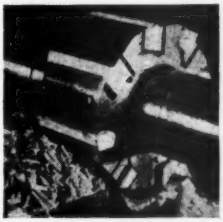


Fig. 1 (left).—Milling cutter with inserted ceramic cutters.

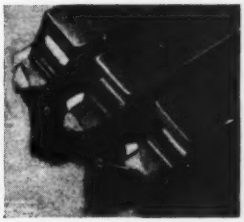


Fig. 2 (right).—Ceramic tools clamped in tool holder.

(a) With boron carbon cutting edge deposited by fusion.

(b) Aluminium oxide edge deposited by fusion.

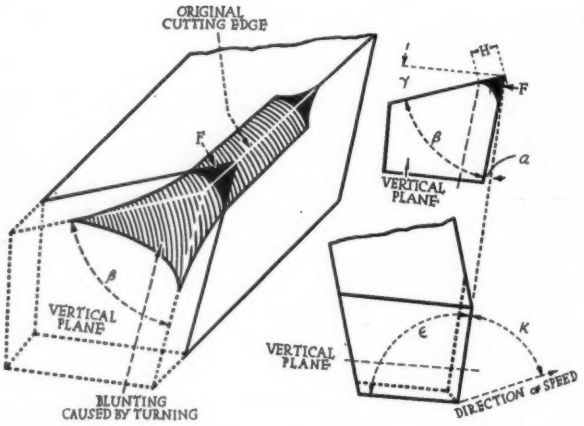


Fig. 3.—Evaluation of the blunting of turning tools by means of determination of reduction of area F of the vertical plane.

The auxiliary cutting edge, which is blunted simultaneously, is reground after each experiment in order to obtain a distinct micrograph. The best magnification is between 50 and 100 times. The area F is determined by means of a planimeter or by counting.

tioned accumulation of heat occurs. This is due to the fact that they do not lose their strength (compression strength up to 100 kg./mm.^{2}) and hardness (up to 9 on the Mohs scale) considerably, even at very high cutting temperatures.[1]

Ceramic tools[2] can be moulded in pressure moulds and extruding presses, in some cases even by casting, and smoothly finished products can be obtained. In the case of tools of larger dimensions, e.g., milling cutters and saws, it is recommended to mount tips of ceramic materials in a metallic body. (See Fig. 1.) Smaller tools can be made in one piece. Ceramic bodies with cutting edges can be used as turning tools and are usually clamped in a suitable holder. (See Fig. 2.)

A Novel Process for the Manufacture of Ceramic Tools

The author has developed processes for the economic manufacture of ceramic tools[3] with wear-resisting cutting edges. In the case of some of these tools small discs of hard materials[4] were sintered into a ceramic body, in the case of others hard materials have been deposited on the cutting edges of ceramic tools by fusion.[5] The cutting edges of such ceramic tools are provided with grooves or hollows into which the hard material (e.g., aluminium oxide or boron carbide) is inserted and subsequently melted by means of a welding torch or an electric arc. During the melting process the hard material is being preformed by a heat-resisting plunger and pressed on to the ceramic supporting body in order to reduce to a minimum grinding after fusion.

Ceramic bodies have been found suitable as material for the carrier which supports the hard material because they possess a high strength, small degree of elasticity and thermal properties similar to those of the molten material. The fusion of hard material on to the cutting edges of steel tools does not yield satisfactory results on account of the difference in mechanical and thermal properties. It is noteworthy, furthermore, that moulding in the case of ceramic supports can be effected economically and in many ways. Aluminium oxide and boron carbide have up to now been used for the manufacture of tools according to this process. It has to be established by further experiments whether other high melting hard materials[4] are particularly suitable for deposition by melting. The fusion process is carried out in an arc furnace. The arc is struck between tungsten or carbon electrodes. During the melting process the muffle is filled with a protecting gas in order to prevent changes of the hard material. The hard

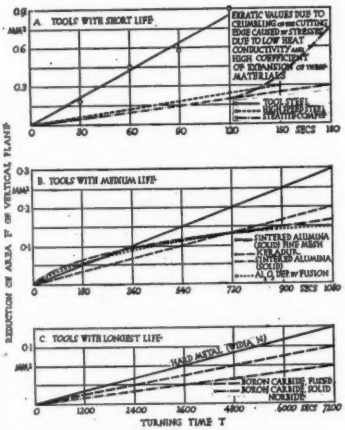

A. TOOLS WITH SHORT LIFE
ERRATIC VALUES DUE TO CRUMBLING OF THE CUTTING EDGE CAUSED BY STRESSES DUE TO LOW HEAT CONDUCTIVITY AND HIGH COEFFICIENT OF EXPANSION OF THESE MATERIALS
TOOL STEEL
HIGH SPEED STEEL
STEATITE COMPOSITION
B. TOOLS WITH MEDIUM LIFE
SINTERED ALUMINA (GOLIATH RUBY MIXED WITH KORUNDUM)
SINTERED ALUMINA (SOLID)
Al2O3 BY FUSION
C. TOOLS WITH LONGEST LIFE
HARD METAL (WIDIA W)
BORON CARBIDE, FUSED
BORON CARBIDE, SOLID NORBIDE
REDUCTION OF AREA F OF VERTICAL PLANE
TURNING TIME T

Fig. 4.—Reduction of area F of the vertical plane of turning tools made from various materials, plotted against turning time. Material: Phenol-formaldehyde resin, type S. Cutting speed v = 250 ft./min. Area of cut, $t \times s = 2 \times 0.2$ mm².

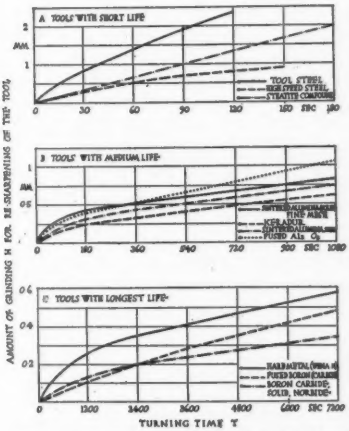

A. TOOLS WITH SHORT LIFE
TOOL STEEL
HIGH SPEED STEEL
STEATITE COMPOSITION
B. TOOLS WITH MEDIUM LIFE
SINTERED ALUMINA (GOLIATH RUBY MIXED WITH KORUNDUM)
FUSED Al2O3
C. TOOLS WITH LONGEST LIFE
HARD METAL (WIDIA W)
FUSED BORON CARBIDE
BORON CARBIDE, SOLID, NORBIDE
AMOUNT OF GRINDING H FOR RE-SHARPENING OF THE TOOL
TURNING TIME T

Fig. 5.—Amount of grinding H for resharpening of the tools plotted against turning time. (Refers to experiments Fig. 4.)

material is pressed on to the supporting body in the liquid state and at the same time densified.

Particularly long life has been obtained with tools which had boron carbide deposited on their cutting edges (see Figs. 4 and 7). Boron carbide[6] of the chemical formula B_4C has a hardness figure of approximately 9.8 (Mohs scale), i.e., it is between silicon carbide and diamonds so far as hardness is concerned.

Tool Life Investigations

The plastics and tool materials shown in Table 1 have been used for the life investigations. The greater part of the experiments has been carried out with a cutting speed v = 250 ft./min. A moulded phenol-formaldehyde resin, type S, was used, which caused extensive wear on all tools in order to keep down the cost of the plastics to be machined. It can be assumed that the experience gained with this material, particularly the sequence of tools according to Fig. 7, can also be applied to other kinds of plastics.

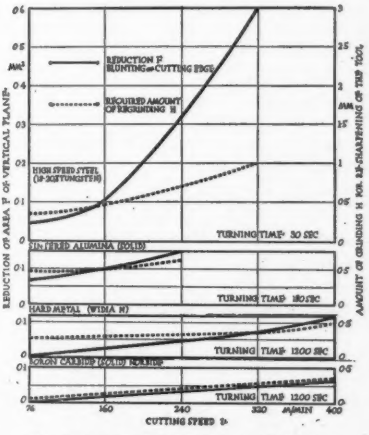

REDUCTION F BLUNTING OF CUTTING EDGE
REQUIRED AMOUNT OF RESHARPENING H
HIGH SPEED STEEL (18-20% TUNGSTEN)
TURNING TIME 50 SEC
SINTERED ALUMINA (SOLID)
TURNING TIME 150 SEC
HARD METAL (WIDIA W)
TURNING TIME 1300 SEC
BORON CARBIDE (SOLID) NORBIDE
TURNING TIME 1200 SEC
REDUCTION OF AREA F OF VERTICAL PLANE
AMOUNT OF GRINDING H FOR RE-SHARPENING OF THE TOOL
CUTTING SPEED v

Fig. 6 (right).—The influence of cutting speed on the reduction of area F of the vertical plane and the amount of grinding required for resharpening of the tools. Material: Phenol-formaldehyde resin, type S. Area of cut: $t \times s = 2 \times 0.2$ mm².

The "re-grinding graph" deviates considerably from the "reduction of area graph" in these tests because the high-speed steel shows considerable wear of the rake angle.

An increase of cutting speed above v = 800 ft./min. has not been possible either in the case of sintered alumina or in the case of Keradur. In spite of repeated tests the cutting edges did not stand up to the high stresses and disintegrated.

Table 1.—Plastics and Tools Used for the Life Investigations.

No.	Plastics
I	Phenol-formaldehyde resin, type S
II	Artificial resin trolon A2 (cast resin)
III	Laminated plastic material (cloth filled) type T3 (Unitex)

No.		Tools. Angle according to Fig. 3					Manufacturer
		α	β	γ	ϵ	κ	
1	Tool steel	10	73	7	90	70	—
2	High-speed steel, 18–20% W ..	10	73	7	90	70	—
3	Steatite compounds*	10	72	8	90	70	Hermsdorf-Schomburg-Isolatoren Ges., Hermsdorf (Thuringia)
4	Sintered alumina, solid	10	72	8	90	70	Deutsche Gold-and Silberscheide-Anstalt, Frankfurt/Main
5	Sintered alumina, solid, fine grain size	10	71	9	90	70	Deutsche Gold-and Silberscheide-Anstalt, Frankfurt/Main
6	Ceramic tool*, with Al_2O_3 deposited by fusion	13	66	11	90	70	Author's own product
7	Tungsten carbide widia N	10	74	6	90	70	Krupp, Essen
8	Boron carbide norbide,† solid ..	10	75	5	90	70	Norton Corporation, U.S.A.
9	Ceramic tool,* with boron carbide (B_4C) deposited by fusion	8	75	7	90	70	Author's own product
10	Ceramic tool keradur*	10	72	8	90	70	Hermsdorf-Schomburg-Isolatoren Ges., Hermsdorf (Thuringia)

* Not yet supplied commercially.

† Has been used in the U.S.A., preferably for machining surfaces of snap gauges, etc., and for sand-blasting nozzles.

The cutting edges of tools when machining plastics wear differently than in the case of cutting light metals, steel or cast iron. In the case of plastics, fissures and cracks occur in the course of the cutting process, not in the same shape as in the case of metals, where the well-known "wear marks"[8] and erosion are caused at the cutting edge. Contrary to this, the engaged cutting edges are surrounded homogeneously by plastic with its blunting effect, causing an almost uniform radiussing with most tool materials as a function of the cutting time. It was not possible to use the width of the wear marks as a measure for the wear of the tools, because in the case of ceramic tools the width of these wear marks could not be recognized. In the course of the present investigation blunting of the tools has been determined in terms of the evaluation of reduction of the cutting edge area, i.e., by determination of the reduction (F) of the area of the plane vertical to the cutting edge (see Fig. 3). The total wear of the cutting edge can be taken as the product of the above-mentioned reduction of area and the length of the cutting edge which is in contact with the job. The result of the investigation showed that three main groups of tool life can be distinguished: tools with a short, medium and long life (see Fig. 7). The amount of grinding required for resharpening the tool after a predetermined cutting time is of importance from the commercial point of view, particularly in the case of expensive tools. Experiments were, therefore, carried out to determine this amount of grinding after each cutting time, and the results have been reproduced in Figs. 5 and 6.

The reduction of the cutting edges of the tool occurs in conjunction with the above-mentioned increase in radius. This leads to an increase in diameter of the job. The data provided in Fig. 5 enable the operator to find out which amount of reduction of the cutting edges can be allowed in the manufacture of plastic parts without exceeding permissible tolerances.

The reduction of area of the vertical plane should not exceed 0.1-0.15 mm.,[2] otherwise the tool starts pushing, the surface of the job becomes rugged, and an increase in diameter occurs, which in most cases is not permissible (taking 0.13 mm.,[2] blunting amounts to 0.25-0.20 mm. with diameters from 10 mm. upwards).

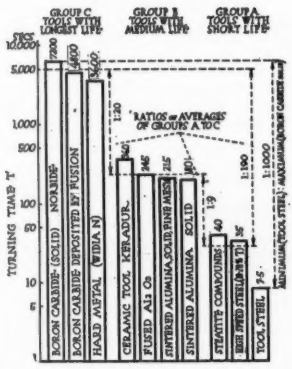


Fig. 7.—Comparison of turning time of tools made from different materials based on equal reduction of area F of the vertical plane.

F was based on 0.06 mm.², which is the maximum figure for sintered boron carbide (Norbide) after 2 hours' turning (see Fig. 4, C.) Material to be machined: phenol-formaldehyde resin, type S. Cutting speed v = 250 ft./min. Area of cut: t × s = 2 × 0.2 mm.² The pronounced difference of turning times is obvious. e.g., tool steel v. boron carbide (Norbide) has a ratio of 1 : 1,000. The data provided for turning times and ratios can also be applied to the cutting volumes obtainable.

An increase in cutting speed is bound to prove detrimental to materials of lower heat resistance (Warmfestigkeit), because of the low heat conductivity of plastics mentioned above. Fig. 6 shows the influence of cutting speed on the blunting of four combinations of tool/materials. In the case of high-speed steel, any increase in cutting speed reduces the life considerably. In the case of sintered alumina (taking the same area of cut), the load on the cutting edge becomes excessive, which results in chipping of this edge. In the case of hard metal and solid boron carbide, the cutting speed can be increased without danger.

The results of these experiments have been compiled in Fig. 7. The considerable difference in life of the various tools is very obvious. Boron carbide in the solid form as well as deposited in the molten condition takes the first place. It may be safely assumed that boron carbide will reach increasing importance, being at present the hardest artificially manufactured material for the machining of plastics.

Boron carbide in the fused and sintered form is unsuitable for machining of cast iron and steel because of its lower strength in the grain boundaries compared with other hard metals. This has been confirmed by experiments carried out by Dawihl and Schroeter.[9] The compression strength of boron carbide is only approximately half that of hard metals. In the case of machining plastics, the specific load on the cutting edge is considerably lower because of the lower strength.

Fig. 7 shows that when machining plastics not only the life of the individual tools vary greatly but also a very considerable difference in wear is caused by the various kinds of plastics. Three of the most commonly used plastics (I, II and III of Table 1) have been employed for comparison tests. The figures for these tests are shown in Fig. 8. Laminated materials with a cloth filler, which are used for bearings on a considerable scale, can be most readily machined. In the

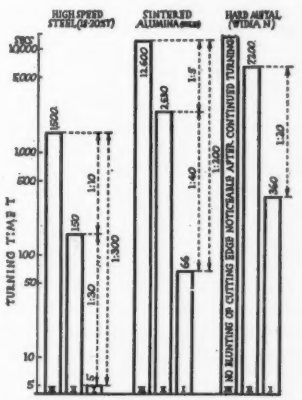


Fig. 8.—The influence of the plastic on the blunting of the cutting edges (v = 250 ft./min.).

The plastic which can be cut most easily (No. III) has been machined with tools Nos. 2, 4 and 7 for a given time in order to obtain ratios of machinability of the three plastics, I, II and III, according to Table 1. Subsequently the turning time for the same amount of blunting has been investigated for plastics I and II. In the case of hard metal (Widia N), plastic No. II has been used as the basic material

case of machining cast plastics, the wear of the cutting edge is approximately 5-10 times that figure, and in the case of moulded plastics 200-300 times that figure. It can be seen from this list that it is possible to machine cloth filler materials economically with the aid of tool and high-speed steels,[10] although their application is limited in the case of cast plastics.

Conclusions

The purpose of the above investigations has been to establish a classification for various metallic and ceramic tools used for the machining of plastics. This has been achieved by determining the wear of the cutting edge represented by the reduction of area of the vertical plane of the tool. A plastic (phenol-formaldehyde resin, type S) with particularly high abrasive properties has been used for these investigations.

Cast resins and laminated materials (cloth filler) have also been tested in order to investigate the influence on blunting of the tools. Considerable variations have been found with regard to the life of the various tools as well as the comparative figures of wear for the various plastics. It is not permissible to increase the cutting speed to an unlimited extent, particularly when using tool and high-speed steels. Apart from providing data for the blunting of cutting edges, the above investigations provide figures for the resharpening of the tools after a definite operating time. Boron carbide has proved to be a particularly suitable material for the machining of plastics.

It can be assumed that the results of the above investigations can be applied to other cutting processes, e.g., the milling of plastics. A considerable amount of research has still to be carried out in order to obtain more information about the cutting process, particularly the heat conductivity of the material and the tool.

REFERENCES

(1) The extreme hardness of some of these compounds which can be used for " machining purposes " has already been recognized by our ancestors. The Stone Age tools are made from porous sediments permeated by SiO_2 (Silex—hard stone). Moulded bodies made from hard materials, e.g., silicon and boron carbide, have already been suggested for rock drills, etc., as early as the beginning of this century. Experiments with tools made from sintered alumina have been carried out in the laboratories of Messrs. Siemens and Halske in 1930. At that stage of sintering technique, however, no satisfactory results were obtained, and mass production of such tools had not been started. **(2)** " Maschinenbau/Betrieb," vol. 16, 1937, p. 188. **(3)** Means have been put at the disposal of the industries for the further development of ceramic tools by the Commissioner of the Four Years Plan Department for German Raw Materials, Berlin. **(4)** With regard to hard materials and their properties I should like to refer to the work of K. Becker: " High Melting Hard Materials and Their Technical Application," Berlin, 1937. **(5)** Hard facing alloys, particularly such of a tungsten carbide basis, have been manufactured by Messrs. Friedr. Krupp, Essen, and deposited by means of a welding arc. These have been used for steel tools such as drilling devices, aircraft skids, etc., in order to increase their wear resistance. See C. Agte and K. Becker, " Hard Metal Tools," 2nd Edition, Berlin, 1937, pp. 12 and 28. **(6)** " Maschinenbau/Betrieb," Vol. 14, 1935, p. 618; vol. 15, 1936, p. 13; vol. 16, 1937, p. 368. **(7)** Each experiment could only be carried out once on account of the expense. It can be assumed, however, according to the trend of the graphs, that no considerable deviations should occur when repeating these tests. It has been established that keeping all test conditions constant, the values for blunting of the cutting edges vary about $\pm$ 6 per cent. when using tools made from sintered alumina and tools hard faced with molten boron carbide. **(8)** A. Wallichs and F. Hunger: Examination of Turning Properties of Light Metals, " Maschinenbau/Betrieb," vol. 16, 1937, p. 81. **(9)** W. Dawihl and K. Schroeter: Experiments Concerning the Properties of Pure Boron Carbide as a Tool Material. " Werkstatt Technik," vol. 31, 1937, p. 201. Abstract from " Maschinenbau/Betrieb," vol. 16, 1937, p. 368. **(10)** The wear of the tool can be reduced by chromium facing of the cuting edges. It has been found that the life of a tool steel can be increased by two to three times; in the case of hard chromium facing still better results will probably be obtained. The use of cooling media in order to reduce wear of the cutting edge has not proved to be satisfactory.

Synthetic Insulating Resins

By Dr. C. F. HILL

(Manager, Insulation Department, Westinghouse Research Laboratories)

BASIC chemical research accelerated by the war is responsible for the development of two synthetic resins—these resins are new, they have unusual properties, they are important now, and promise to be even more important in post-war applications. Authority insists that nothing can yet be divulged chemically. The first, now being applied to radio and radar units, is Fosterite, a remarkable solventless impregnant giving 100 per cent. fill and, in addition, a moisture-proofing material. The second is a synthetic resin to replace shellac, surprisingly strong and definitely superior to natural shellac for some very important applications.

Fosterite

For 20 years the electrical industry has been talking about the ideal impregnating material for insulation in coils and apparatus. It is quite evident that solvent-type varnishes which are 50 per cent. solvent cannot give more than 50 per cent. fill. The two most desirable but elusive properties of such materials are (1) usability without a solvent and (2) a 100 per cent. filling of all space within the insulation. We have now obtained these properties in a new resin, Fosterite. During the impregnation of the coil or device, Fosterite is in a liquid state, but the "solvent" reacts with another resin dissolved in it, and the whole mass turns to a tough solid. It is solventless in that the whole of the liquid resin reacts under heat to form the infusible solid: there are no by-products of the process that must escape as in most resin reactions.

The additional problem of keeping the resin from running out while it is being polymerized to a solid has also been solved, and we now have both an excellent material and a satisfactory processing method. Actually, this resin is not just one resin, but a family which makes it possible to obtain a wide range of properties by suitable modifications.

This family of resins is giving some very interesting results in application, both for the filling and coating of insulation. The complete filling allows much higher voltage gradients to be used than for normal materials. On one small radio transformer, for example, Fosterite provides four to five times the dielectric strength that was obtained with former materials. This permits a radical reduction in size and weight.

Moreover, the elimination of voids in coils increases the heat conductivity of the structure. Preliminary experiments have shown that certain coils impregnated with Fosterite resin will dissipate as much as one-fourth more heat as coils impregnated with ordinary solvent-type varnishes. In addition, a sample of Fosterite, heated in transformer oil at a temperature of 185 degrees F. (85 degrees C.) to 194 degrees F. (90 degrees C.) for one year, swelled less than 1½ per cent.—indicating that it is insoluble in transformer oil and hence suitable for treating oil insulated coils.

While Fosterite was developed as a solventless varnish for use in standard electrical equipment, it is also finding application in highly specialized communication equipment for the armed Services—both in radio and radar—where moisture proofing is the most critical factor. The Fosterite method now promises to solve this important problem.

In a test of Fosterite moisture proofing, radio and radar components are subjected to hot and cold water submersion. The objects are first placed in 149 degrees F. (65 degrees C.) saturated salt water solution for two hours, then in a 32 degrees F. (0 degrees C.) solution for another two hours, and the cycle is repeated five times. The insulation resistance must not be less than 75 megohms; the leakage current not more than 3 milli-amperes.

Surface coating has also provided a radical improvement in moisture resistance of such apparatus. By means of the coating and impregnation, the moisture proofness is 100 to 1,000 times better than by the use of the best previous materials.

Fosterite is going as rapidly as possible into radar and radio communication equipment for the armed forces, but we can also anticipate its wide use after the war. At present our efforts are confined to war-time applications not only at Westinghouse, but

at other companies to which it will be furnished.

New Synthetic Resin Replacing Shellac

Fosterite is an example of the development of an entirely new material. Older materials, on the other hand, stimulate scientific efforts to discover improvements or similar but better materials. Typical of this latter kind of development is the discovery of a synthetic resin, a strong and new resin superior to natural shellac.

At the beginning of the war we were faced with the prospect of losing our shellac supply, since all of it comes from India. Moreover, made by small insects from the saps of several kinds of trees and varying in quality with the seasons, natural shellac is an extreme example of a product full of impurities. Yet one highly important and troublesome electrical device—the commutator of rotating machines—has depended completely on shellac as a bonding insulating agent.

While shellac had given much trouble, extensive research provided no substitute. The war, however, stimulated more research and again a discouraging search for substitutes began. Our chemists again took the shellac molecule apart theoretically and postulated another hypotheses as to the type of the desired resin—the result was the strong, new synthetic resin.

Mechanically and electrically, the synthetic resin appears to have all the properties desired; indeed, the new resin appears to be an improvement over shellac at its best for commutators and in certain other electrical insulations. This material now promises not only to eliminate shellac but also its associate, mica (used in combination with shellac in commutators), thus eliminating another headache.

The unusual elasticity and strength of this resin indicate that it will find other applications. For example, fibre-glass bonded with this resin has a tensile and bending strength equal to that of rather strong metals—75,000 to 80,000 lb. per sq. in. In other words, this plastic is stronger than cast iron which has a tensile strength of 15,000 to 50,000 lb. per sq. in., stronger than sheet brass with a tensile strength of 40,000 to 70,000 lb. per sq. in., and as strong as many steels (tensile strength, 80,000 to 300,000 lb. per sq. in.).

With these two resins, basic research has solved three important problems of the electrical industry. The problems were to find (1) a solventless impregnant to give 100 per cent. fill, (2) a moisture-proofing material, and (3) a shellac substitute. These are three very important problems to the industry, but what I would like to emphasize most is that they were solved by basic chemical research. Fosterite and the synthetic resin replacing shellac in many critical applications are typical products of systematic, basic research in industry.

BRITISH STANDARDS INSTITUTION

Lord Woolton Elected President

THE annual general meeting of the British Standards Institution was held on October 17, 1944.

The Right Hon. Lord Woolton, C.H., P.C., was elected president of the Institution and Sir Percy Ashley, K.B.E., C.B., was elected vice-president; Sir William Larke, K.B.E., succeeded Sir Percy Ashley as chairman of the General Council.

Dr. E. F. Armstrong, F.R.S., chairman of the Finance Committee, explained that the income and expenditure for the year had increased by 28 per cent. and was now about £69,000. The sales of copies of British Standards had gone up 39 per cent. The Government grant-in-aid was nearly double and was now £12,900. Whilst there was an increase of some 15 per cent. in the number of subscribing members, he pointed out the need for greater support from local authorities and industry.

Review of Work

Sir Percy Ashley concluded his term of office as chairman of the General Council with a brief review of the work done as a direct aid to the war effort by the British Standards Institution and the progress made during the same period in the preparation of British Standards for industrial and commercial materials and appliances. The war work covered the preparation of war emergency British Standards for A.R.P. materials for the Ministry of Home Security, packaging schedules and code for the Ministry of Production—a packaging code for tropical climates being now in preparation, steel and non-ferrous metal standards as well as standards for many other materials, tools and appliances for the Ministry of Supply and for the Services generally, the schedules for clothing and hardware for the Board of Trade. Many

(Continued on p. 529)

World's Industry Employs Plastics

AIRCRAFT

Newest development in riveting of aircraft structures seems to be a preheated hollow plastic rivet which is expanded by compressed air of a few pounds pressure. Numerous thermoplastics were tried out and finally acrylics were selected ("Iron Age," Vol. 154, 1944, pages 52-53, July 27). **Fire-resistant asbestos product** has been developed by United States Rubber Co. for the heating and ventilating air-duct systems of aircraft. The pliable fabric can be twisted and turned or completely deformed, but it returns easily to its original shape without effort. Systems are assembled and cemented together with a special synthetic rubber compound ("Scientific American," Vol. 171, 1944, pages 35-36). **New three-ply laminated plastic sheeting** designed to give added protection to airmen flying in pressurized high-altitude aeroplanes is produced by Du Pont de Nemours. It consists of a single layer of Butacite (polyvinyl butyral) sandwiched between two layers of Lucite (methyl methacrylate). A special adhesive had to be developed to accomplish the lamination. **One-piece Plexiglas canopy,** blown by a new air-forming technique, is manufactured by Rohm and Hass. It gives improved vision to Thunderbolt pilots and reduces weight with the ensuing advantages ("Aut. and Aviation Industries," Vol. 91, 1944, p. 98, July 1). Advances made in the thermo-elastic forming of thermosetting phenolic laminates for semi-structural and non-structural components for aeroplanes are described by Beach in "Machinery," New York, July, 1944.

Protection of aircraft tube assemblies and hexagonal nuts against unauthorized tampering and against dust and dirt is offered by Cel-o-Seal caps. These can be applied by hand at the rate of 20 to 25 a minute. The caps shrink in drying, and conform to the contours over which they are placed. Sabotage, or unauthorized disturbing, is revealed by torn seals.

Propeller blades for the P51 Mustang fighter are faired with a cuff of very light synthetic hard rubber sponge, known as Fairprene. The sponge itself is protected with a layer of corrosion-resistant material. ("Mechanical World," 1944/116/358.)

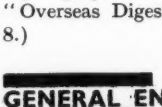
SHIPBUILDING

Gun control grips incorporating three switches for power-driven naval turrets are made of macerated fabric phenol resin. They provide control of gun firing, communication and turret rotation. The same issue contains an editorial summary of plywood, veneers and glues, and forming and joining methods used in fabricating plywood. This 16-page compilation contains, besides tables, numerous illustrations and useful references to textbooks issued on the subject of plywoods between 1938 and 1942. **Fire hazard of paints on metal** has been investigated by G. H. Ingberg, chief of the fire resistance section of the National Bureau of Standards. While a single paint coat is only about 0.001 in. thick, successive applications, such as on ships, may build up a coating of considerable thickness; such paint coatings will burn and contribute to the spread of the fire. The explosion hazard has been

investigated, too ("Technical News Bulletin," July, 1944, page 53). **Phenol-formaldehyde adhesive** has been developed for low-temperature curing by Resinous Products and Chemical Co., Philadelphia, Pa. It is supplied as a viscous reddish-brown solution infinitely dilutable with alcohol and also with water; it proved to be useful in the manufacture of oak ship keels and laminated structural members for heavy columns. **Tail-shaft bearings in plastics** have been examined by Keller with a view to determining liability to swelling ("Kunststoffe," 1944/34/27). The bearings consisted of a number of plastic bars fixed by means of wedges into the bearing bush. Whilst the lignum vitæ formerly used seems to be quite satisfactorily replaced by a cellulose wool filler phenolic, it is suggested that a cotton base filler would probably give better results.

ELECTRICAL

Insulating material for super-high-frequency work is produced by the Monsanto Chemical Co. under the name Styramic H.T. The chemical nature of this material is not divulged; its cost, however, appears to be high. **Insulating varnish of great flexibility and high mechanical strength** has been developed by the Sterling Varnish Co., of Haysville, Pa. The composition is said to be oilproof, resistant to the action of acids, alkalis and water, and to be eminently suitable for high-temperature environment (The McGraw-Hill "Overseas Digest," July, 1944, page 16). Synthetic resin put out by the Westinghouse Co. as a **replacement for natural shellac** still attracts attention. It is claimed that not only does it promise to displace shellac but, furthermore, has advantages as a replacement material for mica in the construction of commutators. Unusually high elasticity and mechanical strength indicate other applications. Glass fibre bonded with the new resin has good bend strength, whilst a tensile strength of 30 to 40 tons to the square inch is claimed. ("Chemical and Metallurgical Engineering," July, 1944, cited in McGraw-Hill "Overseas Digest," August, 1944, page 8.)



GENERAL ENGINEERING

Conventional wood and metal turning equipment is suitable for machining transparent plastics such as Lucite. H. O. Belleville recommends tools with increasing top and side rake for steel-cutting tools to improve performance; on the other hand, the front clearance angle of woodworking tools should be reduced to support the cutting edge. ("The Tool Engineer," Vol. 14, 1944, page 104). The past few years have seen a steady **decline in the use of felt washers or packed glands** which have been replaced by oil seals of unit type, making use of synthetic rubber. Careful investigations on these sealing elements are discussed in a comprehensive report by T. C. Scott ("Jl. Inst. of Autom. Eng.," Vol. 12, 1944, page 161). **Hydraulic accumulators for general use,** produced by Gear Products Co., consist of a seamless steel shell containing a synthetic rubber bladder having an integrally moulded air valve. ("Autom. and Aviation Industries," Vol. 91, 1944, page 82, July 15). **Two-ply transmission belting** by Graton and Knight Co., Worcester, Mass., is cemented together by a celluloid plastic foil. It passes through a solvent bath and is then fed continuously between the two plies of leather, which, together, pass between sets of rubber pressure rolls, and are then wound on a drying drum whilst under tension. **New co-polymer "Cerex,"** containing carbon, hydrogen and nitrogen, is announced by Monsanto. The three elements may be combined in various

forms to give various characteristics. The material is dimensionally stable with a minimum of heat distortion above the boiling point of water; flexural strengths around 5 tons/sq. in. have been obtained. **Problem of corrosion of light-metal screws** of Al-Mg-Si alloy when embedded in phenol resin plastics has been investigated by K. Geyer and L. Reschke ("Elektrotechn. Zeitschrift," Vol. 65, 1944, page 76). Screws with various surface treatments have been tested, and it was found that not the plastic, but the formation of "sweating water" was responsible. **Plastic punches are more pliable than lead punches** and, therefore, give more readily and force the metal to be formed more closely into the die impression. These conclusions are drawn by G. H. Prudden in article "Plastic Punches Facilitate Lockheed Metal Forming" ("Machinery," New York, Vol. 50, 1944, pp. 137-145). **Wartime designs using plastics** are described in a recent issue of "Product Engineering" (Vol. 15, 1944, p. 156, Aug.). A redesigned instrument tester with rotatable table using phenolic plastics for the compound housing and the turntable is noted. As the overall dimensions of each half of the housing are identical, one mould is used for producing both.

MISCELLANEOUS

Impregnated cotton webbing produced by Congolium Nairn Inc., New York, and marketed under the name Leatherlin is said to be stronger than leather, entirely weatherproof and resistant to mildew. It has very high flexibility, a property which is retained without frequent oil treatment. The nature of the impregnating compound is not given. **Permeability to bacteria of acrylics used in dentistry** has been investigated by Rosenthal (J. Am. Dentistry Ass., 1944/31/220). It was found that correctly processed methyl methacrylate is impermeable to B. prodigiosus and other oral flora. Surface grinding does not affect this property. **Value of synthetic resins such as the acrylics in partial dental prosthesis** is discussed by Mann and Applegate, of the School of Dentistry, University of Michigan (J. Am. Dental Ass., 1944/31/505). It is concluded that in the construction of new appliances and in the repair and maintenance of others, these and similar resins have much to offer in the way of increased accuracy and simplified manipulation. **Quick-drying enamels,** improved plywoods and fabrics are dealt with in a comprehensive account in "Scientific American," 1944/177/115. The part played by the plastics industry in these connections is particularly stressed. Vinsol resin, used in asphalt emulsions for the construction of airports and roads, and also finding suitable application in the manufacture of paper board, plastics, cements and paints and varnishes, has been freed for more general use by the American War Production Board. Also released is the plastic binder Truline, used in cores and moulds for foundry work. **Properties of Koroseal,** a plasticized vinyl product developed by the Goodrich Laboratories, Akron, Ohio, are reviewed by Groves in "Practical Engineering," 1944/10/321. Its production is based on U.S.P.1,929,453. The chemical and physical properties and the application of vinyl acetate and P.V.C. are dealt with by Rolfe in the same journal, page 354. The data given referred to Welvic (I.C.I.), Chlorovene (F. A. Hughes and Co., Ltd.), and P.V.C. (B.X. Plastics), and other concerns. **Design of rubber couplings for automobile use** have been investigated by Booth, of Thomson Products. The author of this work deals especially with those employing rubber in shear and those using the material in compression. ("Mechanical Engineering," 1944/66/389.) Numerous accounts of this system of mounting have appeared in the British technical Press during the past two years. The metal component may be steel or aluminium.

PULP PREFORM

Laboratory control beater.

Note: All photographs are reproduced with kind permission of the Bristol Aeroplane Co.

Production of resin-impregnated paper pulp for preforms, as carried out by the Bristol Aeroplane Co.

By
H. Carl Martin,*
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LARGE-AREA mouldings of reasonably high-strength material by simple methods can create a new field for the products of our industry, and this paper presents a possible solution of this problem in a review of the manufacturing methods of pulp preform mouldings.

The present methods and materials available to us for manufacturing high-strength and increased-size mouldings have various advantages and disadvantages and a preliminary survey of a few of them will help to place in proper perspective the claims of the pulp preform method.

* The author read his original paper to the Institute of the Plastics Industry, Western Section, on March 23, 1944; Midland Section, on September 15, 1944, and London Section on October 26, 1944. Since his first reading and following discussions that ensued, Mr. Martin has carried out further development work, and certain subject-matter has been re-edited and enlarged. The lecture is published with kind permission of the Institute of the Plastics Industry.

Laminated Products

The strength of laminated boards and simple laminated mouldings is mainly dependent on the felting of the sheet, that is, the process of forming the paper on the paper machine wire, where the fibres are shaken down into position and much of the loose water removed. This felting depends to a very large extent on the type of fibre and the beating treatment it has been subjected to. Fillers and size do not help to any great extent and are added to the pulp only for reasons of opacity, finish, and to adjust the paper for impregnation or surface coating. Now in laminated mouldings of the usual type a resin-coated or impregnated high-strength paper is used and is tailored to fit the mould, admittedly a very difficult operation in the case of deep, double-curvature shapes, and it is practically impossible to eliminate lapovers and pockets of pure resin. Lapovers result in uneven pressure in the mould and resin pockets weaken the article.

In moulded shapes it is also difficult to

reduce the resin content to the required figure for high-impact strength. This drawback has been overcome to a certain extent by the use of high-density papers, in some cases treated at an early stage with urea resin, and does to a very large extent reduce the tendency of the paper to split when lightly coated.

A laminated moulding process is also in production, in which quite thick sheets are used and tailored on preforming moulds, and very good results have been obtained. However, the butt joints are there and do cause trouble.

Chopped Fabric and Other Similar Products

Excellent moulding compounds have been produced from chopped fabric, chopped string and the American sisal batting, "Corolite."[1] However, these forms of material, excluding for the moment sisal batting, have the drawback of very poor flow in the mould, high bulk factor and produce resin pockets. I am of the opinion that sisal batting is definitely a move in the right direction, but from information published it seems that it consists of raw sisal fibre needled into flat sheets and dipped in resin. Admitting the very high strength of raw fibre, there must be a tendency for the resin to come to the surface of the moulding, and there is no felting of the fibres in the paper-making sense. I hope to show later in this paper that there is in the method of preform moulding outlined a definite chemical and mechanical link up between the resin and fibres whilst in the beater. The sisal fibres of "Corolite" can also, when moulded, be likened to compressed coiled springs.

These, then, are briefly the materials offered for high-strength mouldings, and a table is included listing average impact figures for comparison.

Impact Strength
(Ft.-lb./½ in. by ½-in. Bar)

Chopped fabric phenol formaldehyde ..	.4 to 2.4
Paper laminated phenol formaldehyde ..	.3 to 3.9
Fabric laminated phenol formaldehyde ..	.8 to 8.0
Asbestos laminated phenol formaldehyde	.9 to 5.5
Chopped string phenol formaldehyde ..	2.5 to 3.0
Pulp preform phenol formaldehyde ..	2.0 to 7.5

Pulp Preforms

I have for many years been extremely interested in all forms of pulp moulding and, before synthetic resins were available, constructed many articles of mixtures of pulp, glue, plaster and alum.

The commercial manufacture of such mouldings from paper pulp has been practised for many years, and the process in general use is to beat up the fibres in water, and when the mix is suitably diluted, to suction form on to gauzes held in shape by slotted and drilled bronze tools. Water is then pressed out of the preform, compacting it at the same time, and it is then dried. The moulding is cold pressed to further compact it, followed by dipping in an oxydizing oil and stoving. In many cases the material used is waste paper, and a certain proportion of new fibre may be added.

After trimming and sanding, the moulding is spray finished, usually with cellulose lacquer, and may be further decorated by transfers or silk screen printing.

Quite useful articles are produced, and trays, safety helmets, biscuit boxes, and various domestic and decorative mouldings are made by this method. To illustrate this more fully, three stages of a pulp-moulded bowl are available for examination.

However, the finish of these mouldings compares very unfavourably with the range of articles produced by the plastic-moulding technique; and this can be put down to the fact that in the majority of pulp-moulding plants breaker beaters are used for the pulp, and there is little if any accurate control, and usually when the pulp is mashed up, that is good enough. Also, waste paper, unless specially treated, is not exactly a stable starting point for a smart appearance.

In an attempt to improve the sales appearance and strength of the ordinary pulp mouldings, I carried out a lot of work with different impregnants and finally became interested in synthetic resins. Improved results were immediately obtained, but the mouldings still had badly formed and uneven parts, and

as this fault is purely a problem of the pulp preparation it is advisable at this stage to examine the methods of producing good pulp and how much of the strength depends on the beater treatment.

Excluding, for our purpose, mechanical or ground wood, fibrous material, in the form of wood chips, is first cooked under pressure with either an alkaline or acid solution, the three main varieties of chemical wood pulp being:—

(a) Sulphite wood cellulose produced by the bisulphite of lime process.

(b) Soda wood cellulose produced by the caustic-soda boil, and

(c) Soda sulphate cellulose produced by digestion with caustic soda and sodium sulphate.

This is the so-called kraft pulp.

There are also modified cooking processes for the treatment of straw, cotton, ramie, etc., and other chemical treatments more in the nature of washing treatments for jute, waste paper, hemp, etc.

The slush formed by cooking is washed and screened and fed into beaters. The beating is the most important operation in the making of paper and also has considerable influence on the quality and strength of preform mouldings. To make the operation clear it is very necessary to understand the action of the beater, and a short description of a typical machine follows.

The paper beater or beating engine was invented in Holland about 1740 and is often called a "Hollander." It is an oval tank-like machine constructed of cement or cast iron and made for various capacities. A beater approximately 20 ft. by 8 ft. would hold about 800 lb. of fibre.

The height of the walls would be about 3 ft., and through the centre of this oval tank is a wall 3 ft. shorter at each end and called the "midfeather." In one half of the tank thus formed is a cylindrical beater roll, the diameter being about the same as the length. The roll is fitted with a number of parallel metal bars known as fly bars projecting from the surface of the roll approximately 1 in. and spaced about 2½ ins. apart. The thickness of these bars varies from ¼ in. to ⅝ in. for different purposes, and the pitch also varies.

Directly under the roll is the bedplate, consisting of a further set of bars of about the same thickness, set about ½ in. apart and ground to fit the circumference of the fly bars on the roll.

The bedplate bars are usually set at a small angle to the roll bars, and it can be seen that the action between the bars, if closely set, is very much like a pair of scissors.

For the preparation of pulp for preform moulding I have had best results with fly bars and bedplate arranged parallel, although more power is required with this arrangement.

Immediately behind the roll is the backfall formed by building up the floor of the beater and following the curve of the roll to a height approximately on the centre line of the roll. This peak falls away rather sharply and then gradually around the beater to the front of the roll.

When the slushy pulp is fed to the beater and the roll is revolving, it is picked up by the fly bars, wiped across the bedplate and forced over the backfall. Thus a continual circulation is kept in operation. The roll is finely adjustable up and down and the gap between the fly bars and roll can be very accurately controlled. The action of the beater on wet stock is very complex, as by lowering the roll quickly it is possible to cut the fibre up considerably or, by gently lowering the roll the fibres can be brushed out and in certain cases fibrillated, i.e., the ends can be beaten out somewhat like the roots of a tree.

A further, and especially important, action of the beater is the hydration of the fibre, the term in this instance meaning the chemical combination of the water with the cellulose of the fibre. I have proved, in my pilot plant, that certain resins, when precipitated in the beater with the stock hydrated to a certain point, will chemically combine with the cellulose and produce something more than a mere impregnated preform. The exact reasons why this occurs are very difficult to investigate, but it does seem to have a

very definite relation to the charge of the cellulose hydrate and the charge of the resin. I believe that when precipitating the resin the hydrate becomes positively charged, the resin remaining negative, thus obtaining the necessary attraction.

However, in practice the method outlined later in this paper works, and no doubt, I have now thrown a very heavy double-ended spanner amongst the technicians of the paper industry.

Reverting to the hydration of the fibre, some types of fibre, manilla in particular, upon prolonged beating forms a gelatinous mass useless for paper making, but capable of being formed into blocks which machine with very similar characteristics to vulcanized fibre. The water absorption of such beaten stock is high, but the impact strength and toughness are also high and a line of thought on good impact strength plastics is opened here, if, by addition of a synthetic resin, the properties lacking can be considerably improved upon.

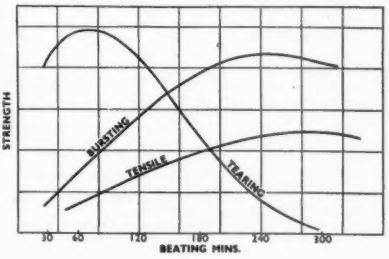


Fig. 7.—Typical beater curves showing increase and decrease of strengths with time.

To return to the beater, as the beating is prolonged the tensile strength of the felted sheet increases in an evenly rising curve and then on over-beating gradually falls, and typical beater curves made from pulp produced in our laboratory machine are shown in Fig. 7. The beater is emptied when the pulp reaches the required state and there are many tests for judging the correct beating time from the operator squeezing up a handful of stuff to accurate drag meters.

In early work carried out it was thought that a sheet of pulp formed at the peak of the tensile curve and then impregnated would produce the strongest results, but it was found that in hot pressing there was a tendency for the resin to migrate to the surface and leave the centre starved and brittle. It was later found that there is a position of the beating curve after the peak that makes an impregnated sheet with much higher tensile and impact strengths, but the resin had to be applied by vacuum and pressure.

Further work was carried out and it was fairly obvious that impregnation was not the answer to successful plastic pulp moulding and that some other way of incorporating the resin would have to be devised. Apart from this there was the question of solvents, changing viscosity of the resins and many other practical production problems.

Attention was then turned to the possibility of adding resins in the beater in the same way that the papermaker adds the size and fillers. At first commercial moulding powders, ground to a very fine mesh, were tried, but were not very successful, as when the pulp was diluted for forming there was a tendency for the powder to settle out. In other words, there was no mutual attraction between the fibre and resin.

Emulsions were then tried out together with precipitation on to the fibre and gave most promising results.

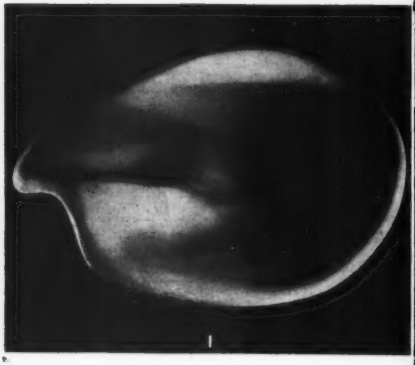
The following method of manufacturing resin containing preforms is being successfully used: — The fibre chosen is first cooked under low pressure in a caustic soda solution of about 12 per cent. to remove mainly the water soluble products. Any lignin present is useful and cleanliness from the papermakers' point of view is not required. The cooking is followed by seasoning for a few days and then thorough washing in warm water.

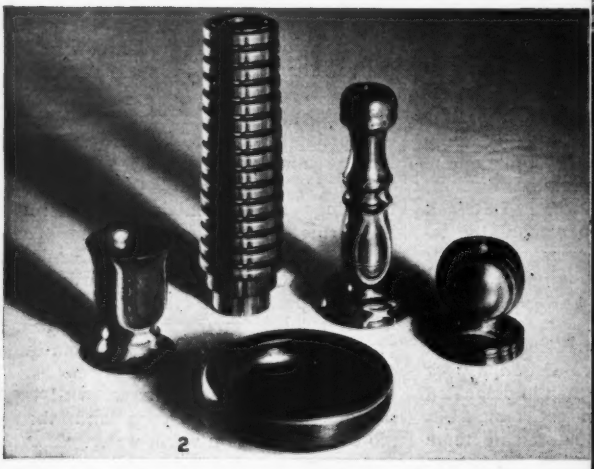
It may not be necessary to cook materials in practice, as very good-quality

Fig. 1.—Pilot's seat moulded from preform.

Fig. 2.—Objects machined from solid block made from resin-impregnated pulp. Note grain effect.

Fig. 3.—Pilot plant beater.





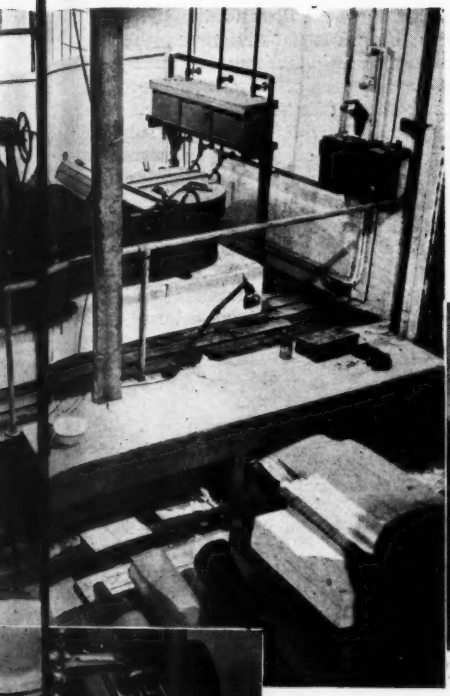
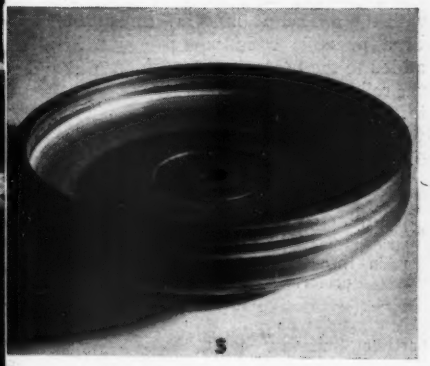


Fig. 4.—Seat preform being removed from forming tank.

Fig. 5.—Bowl moulded from preform.

Fig. 6.—Another variety of objects showing machinability of the compressed pulp.



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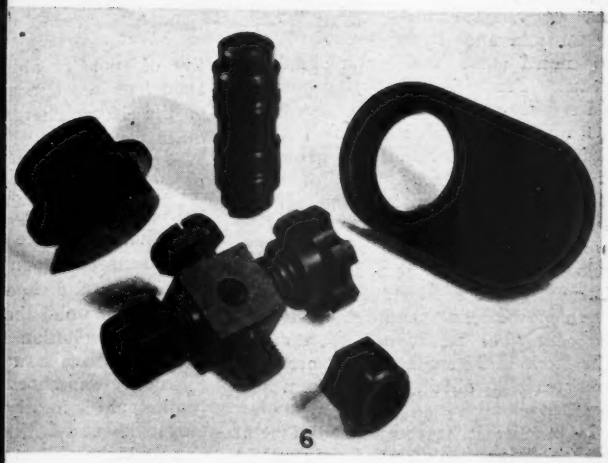

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pulp sheets are available and should, in most cases, meet requirements. I do think, however, that the pulp makers remove too much of Nature's products when manufacturing the pulp.

The slush is fed to the beater and the roll gently lowered from 0.120 in. to 0.002 in. over a period of five hours. This period would vary with different beaters and different fibre, but has been found correct with the type of beater used in our plant.

After about three hours' beating and with the roll set at 0.009 in., an emulsion of a phenolic resin is added to the beater and the roll lowered to 0.006 in. After half an hour the roll is lowered to 0.003 in., and after a further half an hour sodium aluminate is added to the beater to precipitate the resin. At this stage there is an obvious visual change in the mix and it can be noted that the water gradually clears. Precipitation at the optimum pH is fairly rapid and half an hour before the finish of the beat aluminium sulphate is added to adjust the pH to 4.6 to 5.0 and the roll set at 0.002 in. When the beat is completed it is emptied into a stock tank and allowed to season for two or three days before dilution. The pulp at this stage is at 5 per cent. consistency, but is considerably improved if one has a beater to handle it at about 7½ per cent.—our beater will not do this. The stock is then diluted to ½ per cent. consistency to obtain easy uniform preforming.

Fig. 8.—Ashtray pressure-moulded from resin-impregnated preform.

In practice it has been found that at least 8 per cent. on the solid resin weight of sodium aluminate would have to be added to the pulp and the pH would then be about 9. However, this percentage causes excessive foaming and about 5 per cent. is normally used, the completion of the precipitation being carried out with aluminium sulphate. Precipitation of the resins can be obtained by various other means, in some cases even water will precipitate them, but it is more than precipitation that is required. *The resin flocs must be attracted to and retained by the fibres.* By using sodium aluminate and aluminium sulphate we have a large quantity of spots of alumina on which the resin flocs are deposited. This depends on the electric charge of the alumina, in other words, the pH. This is purely hypothetical, but it would seem that the alumina is bound to the fibre and one valence bond linked to the resin.

Sodium aluminate contains aluminium in the negative ion and its use with aluminium sulphate allows control of the total alumina and the pH.

The precipitation of resins from an emulsion forms a most interesting and instructive experiment. If some of the beaten pulp is loosely spread on a microscope slide and a little of the resin emulsion added, the Brownian movement can be distinctly seen, but, on gradually

adding sodium aluminate and aluminium sulphate the resin spots migrate to the fibre. Any amount of washing seems to have little effect in removing them.

In practice it was found necessary to complete precipitation and binding to the fibres with aluminium sulphate, and at the same time correct the pH for easy removal from the forming screens as an alkaline pulp sticks to the screens and forming is not even.

The diluted fibre in the stock tank must be kept agitated as there is a tendency to settle, and a very efficient method must be used. Measurements in our plant are made by volume.

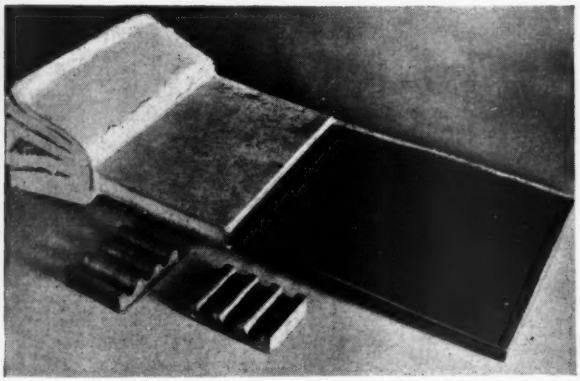


Fig. 9.—Preformed resin-bearing fibres pressed into board showing flow of resin under pressure.

The stock is fed by centrifugal pumps to measuring tanks connected with vacuum-forming tanks or overhead vacuum-forming gear.

The preform is made in the usual manner on a wire gauze and can be dried by a current of warm air in some form of tunnel drier. There is a certain amount of shrinkage and distortion, but this is not serious enough to warrant any special form of drying jig, and we have had quite successful drying by stacking the preforms one on top of the other and putting the pack in the drier overnight. Temperature must be kept low for obvious reasons. The preform is then ready for pressing.

In vacuum forming the preforms, it has been noted that by varying the amount of vacuum it was possible to obtain two types of structures. On the one hand, a high vacuum tends to pull down the fibres and form a laminated article, whilst a low vacuum seemed to mat the preform together much better. From these results a system of preforming was evolved and found to be thoroughly satisfactory by which the article was first formed by a low vacuum and then compacted by increasing the vacuum.

Another point that needs careful attention is that in the preforming of deeply drawn objects there is a tendency to form a much thinner section on the edges, the shape acting as a bowl and the pulp inside drawing down thicker in the middle. This is particularly troublesome with mixes carrying a heavy resin content, but can be overcome to a large extent by careful drilling of the backing tool. It can also be corrected by back drilling of the suction holes with a larger drill so that they form small individual boxes. It is a fault not encountered when using the overhead vacuum tool system.

The big advantage of tank forming being that one can obtain a much thicker preform, and it is not especially necessary to install any form of consistency control. Up to the present I have done very little overhead work, but intend to rectify this omission at the earliest opportunity.

Some of the difficulties that must be overcome before pulp moulding can

become general and hope to compete with powder moulding are:—(a) The resins have, at the percentage required, a tendency to make the pulp very wet and difficult to form. With some emulsions the precipitate is very fine and blocks the screen quickly with many other attendant troubles.

(b) The bulk factor is very high, but can be considerably reduced by rubber-bag pressing the wet preforms. This also has the advantage of removing a lot more water, but, except for very simple shapes, solid tools cannot be used as pressure must be evenly applied all over the preform to compact it equally.

A certain amount of work has been done by pressing with heated fluid pressure on vacuum tools, which helps remove a greater quantity of water and slightly flows the resin.

(c) Except by dipping or spraying before final hot pressing it is difficult to produce mouldings all exactly alike in colour, and I have had some remarkable effects of a perfect finish on one side of an article and a very poor finish on the other. This has been reversed in the following moulding and it is very difficult to trace the real reason.

One finishing method that has proved of exceptional interest is to dip the preform in an emulsion which will produce a very high resin content surface. Care must be taken, however, in drying out the water as the resin forms a skin on the article and tends to trap the moisture in the preform. Of course, certain articles can be sprayed afterwards with a baking finish, and it is interesting to note that in all reports of Henry Ford's plastic car body it mentions spray finishing. Nowadays, with the exceptionally good finishes obtainable and with infra red drying, spray finishing is not a very serious drawback.

Since reading this paper to the Western and Midland Section of the Institute, a considerable interest has arisen in the exceptional machining properties of blocks of material made by my process. This was quite an unexpected field and I have therefore had some specially prepared machined specimens for your examination. You will note that they are shapes that would be extremely fragile if machined from laminated sticks.

I have also received the following preliminary electrical report:—

We have taken a number of tests on this sample both for water absorption and electrical breakdown. I would summarize the results as follow:—

Water absorption per sq. in. of surface exposed to water.

(a) Polished surfaces only exposed to water, 0.0071 per cent.

(b) Polished surfaces removed and exposed to water (i.e., untreated surface), 0.023 per cent.

Electrical tests indicate that the material is quite good and is of laminated construction, having an anticipated electrical strength across the laminations higher than the strength parallel with the laminations.

Future Developments

There is a big field of experimental work and development yet to be explored on this subject, and it may be possible to produce very high strength mouldings by polymerization in situ of a monomer. By this some simple scheme of dipping is visualized, followed by pressing with warm tools to complete the polymerization. A catalyst could be used and the monomer could be partially polymerized.

A lot has been written about the Pittsburg Glass Co.'s Allyl Resin C.R.39 in conjunction with low-pressure laminates, and, judging from these reports, it would seem to have the properties required for low-pressure, richly coloured, preformed mouldings.

There is a further system of making impregnated preforms, which consists of forming the resin in the beater. Water, aniline, hydrochloric acid and formaldehyde are used and the resin is formed by the application of heat. Pulp and water are added to the beater with milk of lime and the beating carried out in the

usual way. The process is outlined more fully by Carleton Ellis in his book.[2]

The pulp preform fits the mould, everywhere, and the slightest flow of the resin completes the moulding. As with other high-strength material, inserts can be used with discretion, but may be a little easier to apply in pulp moulding, as the preform would be punched to fit snugly over the insert, and as the material itself does not flow as with other high-strength moulding materials, it may be that inserts can be applied with far less attendant difficulties.

Conclusion

Pulp moulding can enter the field in serious competition with powder mouldings, particularly in the range of large articles. Mass-production methods are applicable to the manufacture of these preforms, and automatic machines have already been produced for the manufacture of simple pulp-only moulds for packing bottles and containers of various sorts.

I realize that much has been left unsaid in this short paper, but the subject is vast, and covers the arts of paper-making with its attendant troubles, resin manufacture, to say little of the troubles of the moulder.

Acknowledgments

In conclusion, the writer wishes to thank the Bristol Aeroplane Co., Ltd., for permission to publish this paper, and for the facilities made available to carry some of these theories into practical application. The groundwork of a useful type of moulding has been laid.

Thanks are also due to Messrs, I.C.I., Ltd., Messrs. Birkbys, Ltd., Messrs. Catalin, Ltd., British Resin Products, Ltd., and others for their patient co-operation.

REFERENCES

(1) *"Modern Plastics," March,* 1942. **(2)** *"The Chemistry of Synthetic Resins," Ellis, pages* 693-694.

BRITISH STANDARDS INSTITUTION

(Continued from p. 516*)*

of the war emergency standards were made compulsory by the issue of Statutory Rules and Orders.

Sir Percy pointed out that the post-war reconstruction work was now beginning and would increase. The preparation of standards for building materials and appliances now being carried out in support of the programme of house building of the Ministries of Works and Health had already reached substantial proportions. Many other standards were in course of preparation.

Importance of Independent Standards

Sir Percy concluded by saying:—Industrial standards—providing for accurate and precise trade descriptions, methods of sampling and testing, and standards of performance—are likely to be increasingly desirable. If they are to meet the general acceptance they must be prepared and promulgated by either a Government Department or an independent body—independent, that is, in the sense I have indicated, set up and maintained by the national industry as a whole, with Government support but not under Government control. Such an organization has been built up during 40 years in the British Standards Institution. That British industry would prefer it to any form of Government Standards bureau I have no doubt, just as I have no doubt that though it may be necessary in some cases for Government to enforce the observance of standards, yet broadly progress will be most widespread and continuous if the policy of "standardization by consent" is consistently pursued and if whatever changes in organization and methods may be made from time to time the principles on which this Institution has been so successfully built up and developed are steadily maintained.

The meeting terminated with a high tribute to the exceptional services rendered by Sir Percy Ashley to the Institution and through the Institution to industry as a whole, not only during the five years of his chairmanship of the General Council, but during the very many years of his association with the work of the Institution.

Plastics in Tool, Jig and Fixture Construction

Continuing his paper on plastic engineering tools the author deals here in the main with the work of the Vega Aircraft Corporation.

By E. E. HALLS

Fig. 3.—Casting of Vega tools with liquid phenolic resin, is followed by a curing period of 2-8 hours at 175 deg. F.

THE Lockheed and Vega Aircraft Corporations opened an intensive investigation into the possibilities of plastics for the tooling of aircraft because of the anticipated shortage of supply of metals. The research led to considerable success, and by 1942 plastic tools that would withstand 8,000 lb./sq. in. under hydraulic presses were in use. The plastic used is a phenolic resin, the filler material is the ordinary walnut shell finely pulverized, and the chief items of chemical plant involved are mixer and ovens, items as used in the bakery business being adopted. Some data appertaining to the plastic practices of these aircraft concerns were given in "The Modern Industrial Press," Vol. IV, No. 6, July, 1942, under the heading of "Plastics in Aircraft Tooling," and the following notes are taken therefrom.

M. Basolo, foreman of the Lockheed wood shop, conceived and patented the idea of securing drill bushes to the master part, placing the master part in a form and then pouring a moulding material around it. When the moulding material has solidified around the form of the component the bolts fixing the bushings in position are removed and the jig can be finished ready for use. He was led to this invention by virtue of the fact that the use of wood with inserted metal bushings was attended by too many disadvantages for rapid production, viz.:—

1. Slow and expensive operations are entailed if wood is used, because, since a three-dimensional contour has to be made, this entails too much manual work.

2. Bushings must often be retained by means of steel nests or straps and this creates a layout problem with the associated time and expense entailed as

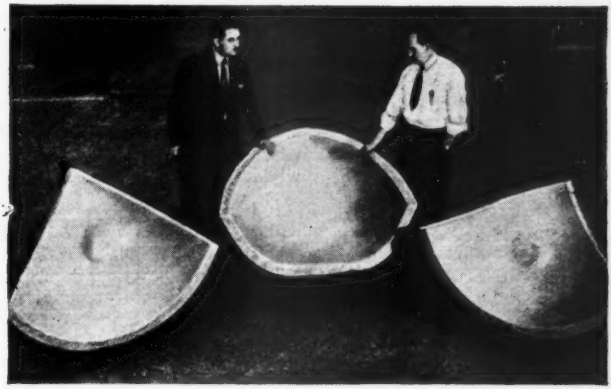


Fig. 4.—These phenolic forming dies are the largest ever made by the company. Cost is lower than dies made formerly, and much time has been saved.

well as the extensive use of machine tools.

3. Wood is readily affected by moisture, as well as by soluble cutting oil emulsions, and it therefore requires efficient surface treatment and regular maintenance if adverse effects of swelling and shrinkage are to be avoided.

The use of a thermoplastic material overcomes these difficulties, but the plastic must fulfil the following criteria:—

(a) It must be possible to use an aluminium alloy component as the master without it being damaged by the temperature of casting or baking.

(b) It must be possible to drill the work, using the normal coolants without heat of drilling adversely affecting the plastic jig.

(c) In consequence of (a) and (b), synthetic plastic is required that can be cast at 225 to 325 degrees F., and the minimum softening point of it must not be below 200 degrees F.

(d). It must be possible to reclaim the plastic by simple and inexpensive processes in order that it can be used over and over again.

(e) The cast tool must respond to finishing by means of the orthodox woodworking tools.

Fig. 5.—Vega sheet metal worker inspects part after forming under press using thermosetting dies.

(f) The cast tool naturally must possess sufficient strength, especially to shock or impact, to withstand shop handling.

(g) The cast resin must not exhibit brittleness at low temperatures.

(h) The cast material must not be susceptible to ageing effects and become embrittled with time.

(i) The plastic tool or jig must not be adversely affected by the various lubricating oils or coolants that are likely to be encountered during production operations, nor must it deteriorate by contact with metal chips from the machining operations.

(j) During the casting and curing operations in the making of the plastic jig, the plastic mixture must be one such that it is under complete control during the operation; this particularly refers to shrinkage, both with respect to uniformity and degree.

The article states that Lockheed, after studying several materials, finally accepted a phenol acetone thermoplastic, whereas Vega adopted a thermosetting composition of acid-setting phenol-formaldehyde base. This composition of resin and acid catalyst or accelerator included as much as 25 to 30 per cent. of walnut-shell flour as filler. Other satisfactory fillers have been established, including wood flour, masonite (a wood product) and scrap plastic.

Confidence had to be established in plastic tools by their use, and after much reserve at the outset they were finally accepted enthusiastically, and firmly established on main assembly lines as well as sub-assembly ones. Among outstanding advantageous features that were proved, the following are worthy of record:—

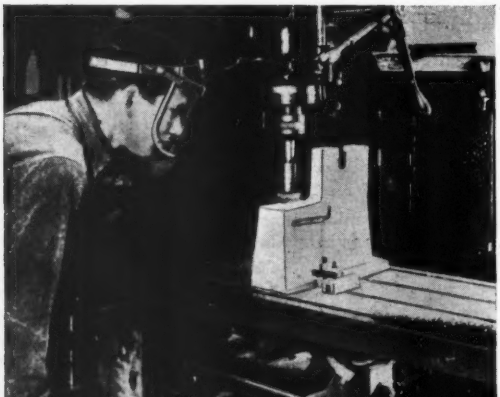


Fig. 6.—The milling of a plastic nesting block at the Vega plant.

(i) In many cases, plastics could be substituted for both steel and duralumin.

(ii) The casting of tools, either to a metal master component or to a plaster cast, is a more rapid procedure than fabrication by forming, milling or hand fitting.

(iii) When duplicate tools are required, these can be made more cheaply than the original because of the fact that the moulds are saved.

(iv) The making of duplicate tools economically and rapidly is a very important feature when they are required for transportation to other plants where the same assembly operations are involved. The fact that such tools are identical in all respects is assured.

(v) The effort in both labour and time for tool inspection is greatly relieved and reduced to a rigid minimum.

The economy in time is the feature

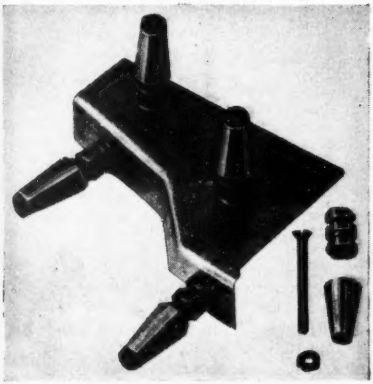


Fig. 7.—Master component template showing co-ordination holes and bolting of drill bushes.

mainly stressed because it is so important to designers, planning engineers, toolmakers and all production people, but assuredness with respect to form and dimensional accuracy, with easement to inspection, is certainly another very important factor.

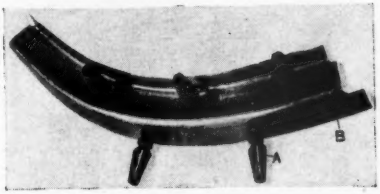


Fig. 8.—Another master component template with bolting arrangement.

It is to be noted that the use of a master component with the synthetic resin technique solves all the problems that arise when engineering data is not to hand and templates are not available, and eliminates the lengthy delays associated with obtaining them. It is only necessary to build up the surround of the master to form a mould to take the proper thickness of plastic. An exact reproduction of the contour of the component is thus obtained without resort to machining and fitting to templates. The Vega Corporation, applying the method to their B17F Flying Fortress programme, claim to have completed the tooling effort in three months and that it would have required from five to six months if wood, duralumin and steel had been employed as in normal practice. They have found plastics to be advantageously applicable to most jigs involving contours, viz., drill jigs, formed router blocks, shaper blocks, saw jigs, checking fixtures, hydro form blocks, dies, punch jigs, forming dies for plexiglass (methyl methacrylate). They claim no advantage in the plastics for jigs in which contours are not involved, other than the conservation of metals.

In the cast phenolic resin jig plates, Vega have not established a satisfactory method of casting the bushes in directly. They drill over-sized holes in the plastic and then cast cerromatrix fusible alloy around the bushings located on the master component by means of pins. The bushings are designed with sufficient wall thickness to deal with the heat of drilling, and dissipate it, without any danger of overheating the plastic and loss of accuracy of location thereby.

A point of importance with regard to the bushings for plastic jigs is the fact that the internal

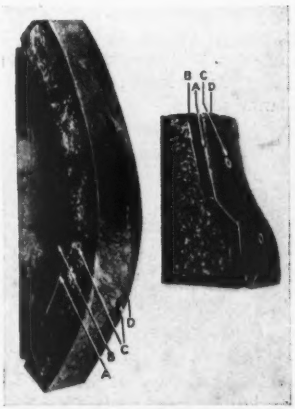


Fig. 9.—Assembly of plastic jig component and nest block. A, part; B, nest block; C, drill bushing; D, drill plate.

dimensions only are of importance, a saving of 50 per cent. of critical machining, and, consequently, the advantage of the corresponding increase in rate of production.

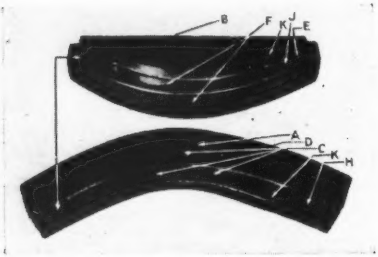


Fig. 10 (above).—Position of alignment bushes. Additional lettering: E, alignment pin; F, co-ordination holes; H, alignment bushing; J, limit locating pin; K, joggle.

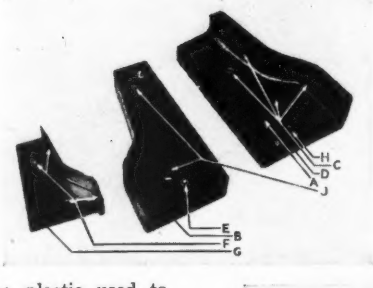


Fig. 11 (right).—Drill jig assembly open; G, master template.

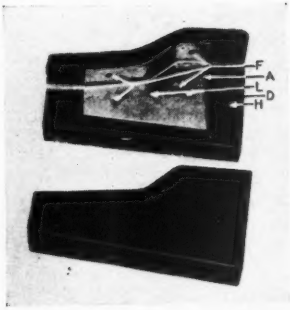
Fig. 12 (below).—Showing open drill jig with component in position. L, pin holes (forming).

The resistance of the plastic used to water and, therefore, to soluble oils, is especially of importance with the router blocks, shaper blocks and saw jigs; distortion as would occur with wood is eliminated and contour and dimensions are maintained.

For hydro-press tools, the tool can be developed with a wooden form block and then a split plaster mould can be made. From this, duplicate plastic tools can be produced, and other spares as required if the plaster mould is retained. The plastic material has been developed for a pressure of about 8,000 lb./sq. in., and provided this limit is not exceeded the plastic will not move under pressure and, therefore, definite mould lines are always retained. Regarding impact, the material has to withstand dropping on a concrete floor, and, of course, it has to withstand the loading or unloading of the jig or the hydropress.

Ageing of the plastic was one of the earlier troubles encountered. A small percentage of maracaibo wax had been added to the mixture in order to improve resistance to soluble oil, and apparently this tended to crystallize, producing wax planes of fracture. Characteristic needle-like crystals consistently occurred in the fracture, symmetrically oriented in the direction of the shear. The difficulty was corrected by reducing the wax addition from 3 per cent. to 0.5 per cent., and this was achieved without losing the quality of inertness to oil.

Another problem concerned the compromise between softening temperature and impact strength, plasticization to improve the latter tending to reflect adversely upon the former. Considerable latitude was found by varying the type and quantity of plasticizer. Early plastics used liquid plasticizers, and it was found that in very hot weather clamping devices on drill jigs would tend to sink into the surface. On the other hand, a solid plasticizer specially developed for the



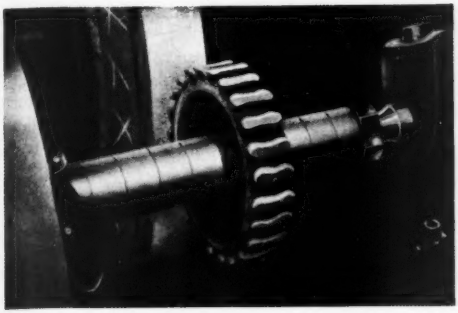


Fig. 13.—Cylindrical grinding of the o.d. of a grinding cutter with teeth built up by welding.

purpose enabled the softening temperature to be raised from 150 degrees F. to 250 degrees F. The resultant plastic had excellent casting properties, high softening point and good qualities in all respects except for failure from excessive brittleness in practice. The desired all-round properties were obtained by compromise, using a judicious blend of liquid and solid plasticizer.

Following the establishment of the best plastic, came the determination of the best conditions for using it, and the Lockheed and Vega Corporations have established such technique to suit the plastics they ultimately adopted.

The Lockheed Corporation use a jacketed kettle fitted with an agitating device. By virtue of the jacket, the resin mixture can be externally heated by means of a fluid whereby uniformity of heating and exact temperature control is possible. Other heating means fall short of this ideal, external electric heating elements most closely approaching it, but not being entirely satisfactory because of local overheating. The agitator paddle is specially chosen to scrape the material from the sides and bottom of the container continuously, as well as to stir; the type used is known commercially as the "full scraper-type agitator."

The Vega Corporation, for their thermosetting plastic mixture, use an ordinary baker's bread mixer for preparing the plastic compound. The baking of the plastic tool is done in a "cookie" oven at 175 degrees F.

The use of walnut shell as a filler is growing considerably in the United States, where, apparently, the practice was first initiated. The material can be ground easily to a fine mesh and gives strong mouldings without too high an absorption of resin. In this country no great use has been made of walnut-shell flour because of its rarity. The possibility of using coconut-shell flour is being examined.

The practices of these aircraft concerns is illustrated by the following, reproduced from "The Modern Industrial Press."

Fig. 3 shows the loading of the thermostatically controlled electric oven with the mould.

Fig. 4 shows several large phenolic forming dies.

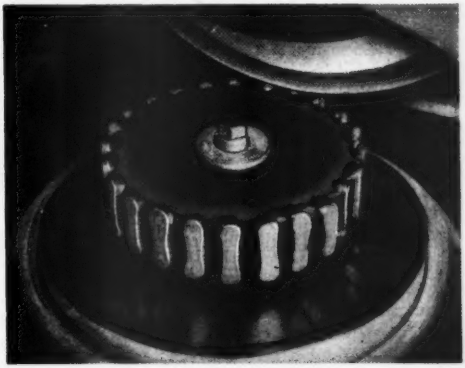


Fig. 14.—Surface grinding of the same cutter as above, using an Arter rotary-type machine.

Fig. 15.—Typical regashing operation on a worn milling cutter. From the point of view of wheel life, resinoid-bonded wheels proved to be 400 per cent. more efficient than vitrified wheels.

Fig. 5 a component from a hydro-press, using a thermosetting plastic die, undergoing inspection.

Fig. 6 illustrates the milling of a plastic nesting block.

As already indicated, the Lockheed practice differs from that of the Vega Corporation, in that the plastic is poured hot, is thermoplastic, and does not require baking. Bushings are moulded in the mass and not fitted subsequently.

Exact information on the chemical composition of this thermoplastic is not available except that it is of the phenolic-acetone type, some knowledge of which has been gained in this country.

Master component templates are the starting point, and those shown in Figs. 7 and 8 show the master co-ordination holes and the method of bolting the drill bushes through them. These assemblies are then placed in suitable retaining forms and the liquid plastic material is poured around them until covered and the bushes surrounded. Shrinkage of the plastic during solidification is catered for by having the retaining form extend above the master part. The hot plastic contacting the component freezes relatively rapidly and solidifies to the contour. Progressive solidification of the remainder of the plastic is compensated by plastic pulled in from the reservoir provided by the retainer and, therefore, upon completion, a sunken top surface results. When thoroughly cold, the plastic cast is removed and the concave free surface is finished flat on the joiner. The conical plugs are removed, exposing the drill bushings. Care, of course, has to be exercised to avoid the joiner blades striking the bushes; actually, the plastic is cut to within $\frac{1}{4}$ in. to $\frac{3}{16}$ in. of the external face of the drill bushing and the hole to the latter is chamfered as a finishing operation. The thermoplastic will not withstand sandpapering, since the frictional heat causes gumming. A spokeshave or floor scraper will give a surface of excellent finish.

Fig. 9 shows the next stage in completing the plastic jig. The master part is placed between the drill plate and the next block and this assembly combination is clamped together. The correctness of alignment between the co-ordination holes in the part and in the drill plate

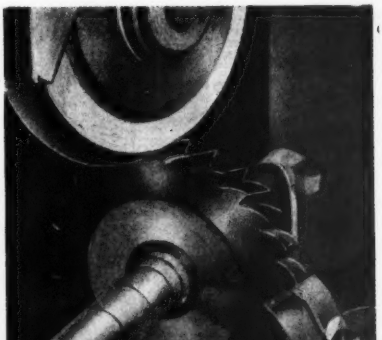


Fig. 16.—Back-off grinding of the tooth with a formed type of resinoid-bonded wheel. Ordinarily, this is a milling operation on the annealed cutter blank.

is checked by the insertion of drill rods of proper size through the drill bushing into the co-ordination holes of the master part. When this feature has been affirmed, holes of $\frac{3}{8}$ in. diameter are then drilled through the ends of the assembled jig to accommodate alignment bushings. The position of the latter is shown in Fig. 10. The jig is then unclamped. The alignment bushes are serrated on their external surfaces, and hold firmly when driven into place. Alignment pins are driven into the alignment bushes in the drill plate and are held in position by flowing a small amount of heated plastic into holes in the back of the drill plate.

Limit pins may be driven into the drill plate at the ends of the master part, or they may be placed through pin holes if they exist in the part for locating during its forming.

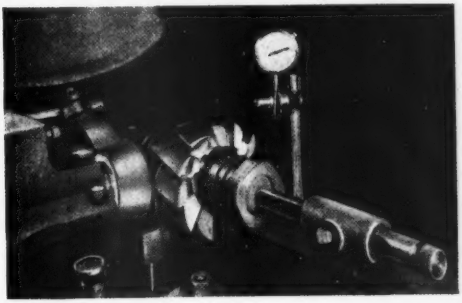


Fig. 17.—Resinoid-bonded cup wheel applied successfully to the all-important finish grinding of the land surfaces of the cutter.

The position of drill bushings in the thermoplastic may be drifted if found not quite accurately positioned during inspection. For this purpose, a drill rod previously heated by means of a torch or blow lamp is inserted in the bushing, a slight dwell is allowed to permit the heat to diffuse into the plastic, and then force is applied in the direction of movement required. It is apparent that some skill has to be acquired for this operation.

Figs. 10, 11 and 12 are of plastic drill jigs, showing the features described.

An alternative method is available for fixing the bushings in extremely large drill jigs. The drill plate and next block are cast as already outlined except that the bushings are not bolted to the master component. The drill jig is planed to the lengths of the drill bushings. The master component is then nested and the holes are back drilled through it and through the plastic drill plate. These pilot holes are enlarged to 1 in. diameter, the drill bushings are fixed to the master component. The latter is then nested into the drill jig, they are clamped together and sufficient plastic is cast around the bushings to bond them to the drill plate. The bushings are dissembled from the master component and finishing operations are as previously described.

The inspected jigs are ready for service and should give extensive life if properly handled. Minor damage can be repaired, but seriously damaged or obsolete plastic tools are returned to the moulding shop for salvage, viz., reclamation of the plastic, of the metal bushings and alignment accessories.

The tool research and development division of the Vega Corporation issue concise notes on the practical application of plastics to their production tool shops. These cover the foregoing points together with practical data.

A. Moulds for All Types of Bases

(1) The greater advantages of plastic tooling for contours than for straight surfaces is strongly stressed.

(2) One method of making the mould is to back the master part with clay or plaster, and to build the sides of the mould around the part, extending the flanges with plaster so as to obtain a larger base or nesting block than the part itself.

(3) An alternative procedure is to use the sample part as a pattern and make a complete mould from it.

(4) Wood is preferable to plaster for the outsides of moulds because it contains less moisture and allows rapid penetration of heat. This ensures a cured casting. In many cases, the surface next to the part can be cast on plaster, and the outer surfaces against wood and sanded later.

(5) When plaster is used entirely, the volume of the plaster should not exceed that of the casting. The thickness of the mould should be kept to the minimum, because of heat generated. This heat is produced when the catalyst reacts with the resin, and, therefore, the greater the volume of plastic the greater is the heat generated, and vice versa. Small castings with thin walls will not generate much heat and curing depends almost entirely upon oven heating. If thick-walled moulds are used, the time for heat penetration is such that long oven times are required to cure the innermost and bottom portions, during which time the exposed top areas become overbaked.

(6) Moulds must be made to facilitate easy spraying and assembly and for convenient pouring of the plastic.

B. Treatment of Moulds

(1) The recommended procedure for all moulds is treatment with one coat of Bayberry wax, allowing to dry and then spraying with at least four coats of clear lacquer, sanding between the two final coats. The lacquer must be thoroughly dry before pouring with plastic.

(2) Wood moulds are coated with four coats of clear lacquer, sanding after the first coat. The last coat should be absolutely smooth. In all cases the casting will reflect all imperfections in the mould surface.

C. Drill Jigs

(1) The above general remarks for moulds apply to all drill jigs. In many cases, it may be desirable to use a plastic base, but a drill plate of other material.

(2) Weight should be borne in mind for all tools. Nevertheless, bases should not be less than 0.5 in. nor over 2.5 ins. thick, and on extreme contours should be in the form of a shell. The bases should always be backed with 0.5 in. masonite to absorb the shock in handling and to protect the edges. The shell can be fastened to the base at the points of contact.

(3) Coarse-threaded machine screws are recommended for attaching wood or masonite to plastics; the screws should be as long as possible, and holes should be drilled and tapped as in steel.

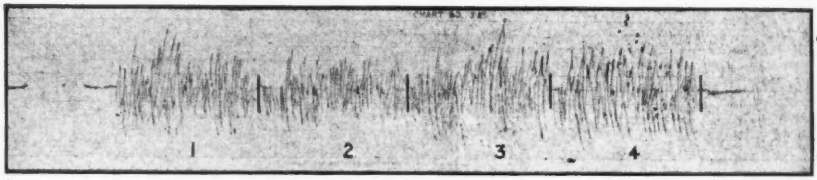


Fig. 18.—Profilometer reading taken on the cutting edges of a milling cutter ground in the conventional manner with a vitrified wheel. The peak-to-peak variance is as high as 50 micro-in. on some teeth.

(4) If using thermosetting plastics, do not cast the bushings in direct, but use the back drilling method and fix with cerromatrix. For pouring the latter, 300 degrees F. is the proper temperature; if it is too hot, the bush will expand excessively and crack the plastic.

(5) Avoid any design involving sharp corners, protruding angles or flanges, in plastics. Breakage or chipping is otherwise inevitable in use. All radii should be as large as the particular tool will permit. The outside radii, which are of no consequence to functioning, should be at least 0.375 in. These can be sanded. Generous fillets should be allowed, but sharp corners are points of weakness.

(6) Wall thickness should be 0.75 in. or over. Drill plates of constant wall thickness should be poured from one end, and, after baking, left in the mould to cool. Thin sections will warp if poured from the flat side.

D. Hold Downs

The standard methods can be employed with the fact always in mind that the plastic drill plate must not be held in strain, and when clamps are closed or tight the jig must be reposing solidly on the surface upon which it is bearing.

E. Drill Bushings

Plastic hexagonal bushings should be used when space is not limited, and gang bushes for confined spaces.

the cast used as a mould for the subsequent operations.

H. Mixing the Resin

(1) The mixing of the resin and other ingredients must be thorough. It is evident that if the catalyst is not uniformly distributed there will be variable curing and some spots that will not cure. Again, if the filler is mixed with the resin before the catalyst is added, the filler will absorb some of the catalyst. Consequently, always mix the catalyst into the resin first and then incorporate the filler. Mixing must continue until all lumps are beaten out of the filler.

(2) An excess of the plastic should always be poured in order to take care of

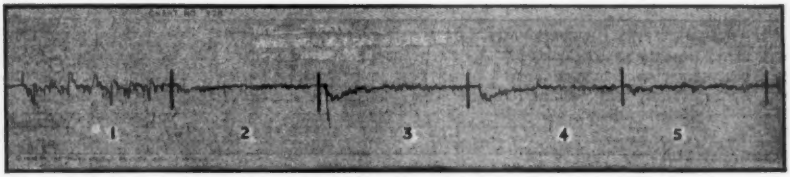


Fig. 19.—Profilometer reading taken on cutting edge of a milling cutter ground with a resinoid-bonded wheel. Note the uniformity of the cutting edges of the different teeth 1 to 5.

F. Marking of Plastic Jigs

Tool numbers should preferably be on the masonite base and when this is not practicable and they are marked on the plastic, they should be applied in Indian ink by rubber stamp before the final coat of lacquer. This protects them against wear.

G. Plastic Form Blocks

(1) The plastic hydro form block should be mounted on a masonite base projecting all round the block for ½ in. Blocks should be standardized 2 ins., 3 ins., and 4 ins. high. For blocks that are to be 2 ins. high, the plastic should be poured 1½ ins. thick. For thicker blocks, 1 in. masonite should be used.

(2) When wooden patterns are made, they should conform to a shrink scale. The Vega resin requires 0.1 in. per foot. A plaster cast is made of the pattern, and

the bubbles which rise to the surface and which have to be machined off. On large castings, this excess should be ¼ in. and on small ones about ⅛ in.

(3) In order to allow time for air bubbles to rise to the surface, all castings should be allowed half an hour to set before inserting in the baking oven.

(4) The following "don'ts" result from experience and experiment:—

(a) Do not lacquer a hot object.

(b) Do not use aluminium lacquer to coat a mould.

(c) Do not pour plastic into a mould if the lacquer is not dry.

(d) Do not place a lacquered mould in the oven immediately after spraying.

(e) Do not use shellac on moulds.

(f) Do not cast around metal inserts without immunizing.

(g) Do not experiment with actual tools.

(h) Do not mix different types of lacquer or thinners.

I. Baking

(1) Baking time is dependent upon the size of the castings, the type of mould employed, and the thickness of material used in making the mould. Strict rules cannot be laid down for baking time and only a guide can be given. The following times are actual baking periods for the plastic, over and above the time required for the heat to penetrate the mould; the baking temperature is 175 degrees F.:—

Volume of casting in gallons.	Baking time in hours at 175 degrees F.
Up to 1	2
1 to 2	3
2 to 4	3½
4 to 8	4
8 to 12	6
Above 12	8

(2) Castings that are still soft and pliable when removed from the mould are in the uncured or "green" condition. The casting should be hard and completely cured when taken from the oven. A casting removed too quickly and replaced, and then put back into the oven to complete the cure, is likely to be replaced out of position, to soften, distort and cure out of shape.

J. General

Plastics are not a cure-all, and one plastic cannot satisfactorily fulfil all purposes. Plastics have their limitations, and much is dependent upon the tool itself and the work it has to do. Close attention has to be given to the design of the tool for plastic, as well as to the plastic composition to be adopted. The users of the tools are closely contacted and use made of their suggestions in relation to handling and usage. This means much in minimizing losses from mishandling and misuse. Attractive appearance combined with light weight and ease of handling, together with the careful thought given to the other factors mentioned, all these features have resulted in successful application in all senses.

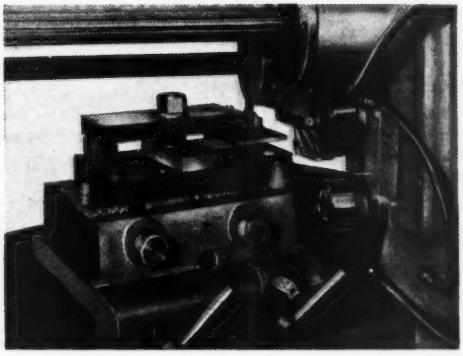


Fig. 20.—In milling stainless-steel turbine blades with the 4-in. spiral slab mill shown in this special "Modern" miller, a 47 per cent. increase in cutter life between grinds was obtained by regrinding with resinoid bonded wheels.

The essential facts borne out by these reports from the Lockheed and Vega Corporations should be carefully considered and interpreted at their true value without exaggeration. These plastic tools are plastic tools in the truest sense. They are made of plastic on site by typical plastic methods. A restricted range of plastics has been explored and exploited. No details of their precise composition is given, but the Vega composition is of a well-established, catalyst-hardened, filled phenolic resin type. The Lockheed Phenol acetone resin is not so well recognized. A large field is already covered, but a wider one remains to be explored.

The chief claim is speed of tool production, and is substantiated. An outstanding feature is the catering for difficult contours—these are catered for, and no advantages are claimed for simple shapes. Shop convenience in handling is automatically furnished, but the shop co-operation in careful and proper handling is a tribute to the real advantages of these tools as well as to the American appreciation of the true spirit of co-operation between technicians and operatives. Thus there is no general claim for plastic tools, only for properly designed plastic tools for purposes in which they can economically and advantageously be employed; the raw material cost and its chief drawback of fragility are not overlooked.

It is also to be noted that the accounts cover relatively large tools, jigs and fixtures for the aircraft industry, for press operations and for assembly operations. The gulf between this sphere and that of the automobile industry, and other large sheet-metal-working industries, is not a wide one, so that the experience gained will no doubt be carefully considered and applied, with or without improvements by further research, as warranted by the merits of the jobs concerned.

Digressing to another class of tool, viz., cutting tools, synthetic resins have also proved invaluable as the bond for grinding wheels. Here, again, the need for improvement, the possibilities of synthetic resins, their patient development in the face of apparently sound opposition, and ultimately outstanding success, has to be credited to America. Some brief account of this work is of interest in showing the reasons for the development and the directions in which notable successes have been achieved. The claims, however, are again restricted to those applications which are advantageous, with no suggestion of encroachment upon other fields.

Fig. 21.—Shell-end mill used in test No. 3. See Fig. 22 for profilometer reading on this cutter.

Synthetic Resin-bonded Grinding Wheels

J. E. Rogers, an abrasives consultant of Toronto, gives an account of the development of phenolic resin-bonded wheels for grinding milling cutters, in an article in "Iron Age," October 21, 1943, page 34. In this he shows how a specialized problem was dealt with in a fundamental way and how the synthetic resin-bonded wheels proved superior to the orthodox type of wheel. The following notes and illustrations are taken from this publication.

The work had its origin in the reclamation of cutters by building up the teeth by welding, the teeth to be welded-on being of a particularly hard alloy steel. Using normal vitrified wheels of various grains and grades, difficulties were still encountered and Rogers conceived the idea that a synthetic resin-bonded wheel would be the most likely solution to the problem. He claims that the success made with this has made available to-day wheels that give improved quality of milling cutter, whereby the protective life of the cutter is greatly increased as well as the grinding and sharpening costs being lowered.

Fig. 13, taken from the original, shows cylindrical grinding of welded high-speed steel cutters with synthetic resin-bonded wheels, which have been in continuous production for several months. With day-to-day checks on the wheel in comparison with the performance of the vitrified type of wheel, these records have shown that the resin wheels result in much faster grinding time on account of their ability to hold their form, cut freely and cool. They did not readily glaze and the thickness of cut has been increased by 50 per cent. without any indication of burning. For example, on shell-end mills the average stock to be removed is 0.050-

0.060 in. Cutters in reasonably good condition can be cleaned up with a stock removal of 0.005-0.010 in. as compared with 0.010-0.020 in. with vitrified wheels, and the time required is about 33 per cent. shorter.

The synthetic resin wheel approaches the ideal in so far as the resin bond gives a cushion to be cut and yet wears away as fast as the abrasive grains become dulled. The records indicate that the resin wheels require redressing every 60 hours of service as compared with each five hours for the vitrified type. This marked saving in production time more than offsets the higher cost of the synthetic resin wheels, this cost being roughly in the region of 4 : 3.

surface grinding, as this has a vital influence upon success and upon wheel life. Actually in the tests soluble oils were used diluted with water 1 : 80.

Fig. 15 shows a regashing operation on high-speed steel milling cutters, this having become an important salvaging or reclamation job. In some plants cutters are annealed and then milled to the required rake and form. However, in the plant of Cutting Tool and Gauges, Ltd., from which all these examples are taken, an all-grinding process employing specially developed machines and fixtures is used. Vitrified wheels were at first employed quite satisfactorily, but now synthetic resin bonded wheels are used with advantage.

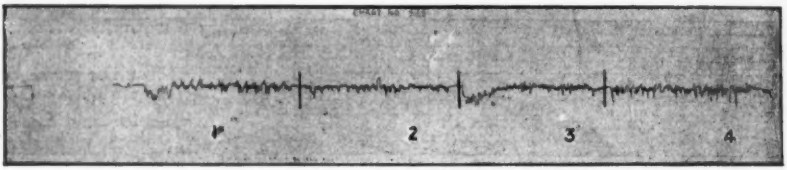


Fig. 22.—Profilometer graph of four teeth of shell and mill ground with resin-bonded wheel, showing good uniformity of edge and an average variation from peak to peak of 4 micro-ins.

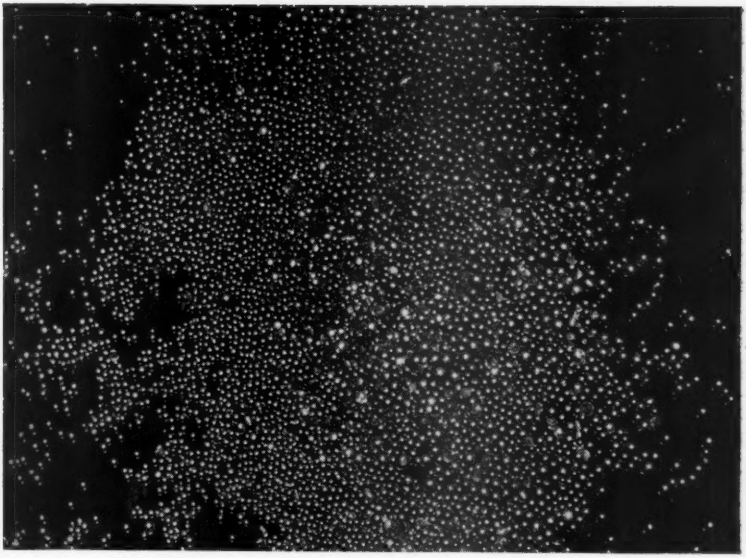
Another factor that should not be lost sight of is the finish produced. The resin wheel gives a finish very much superior to the heavy-grain serration of the vitrified wheel, although the grain size of the two wheels may be the same.

In Fig. 14 is shown an Arter rotary surface grinder. On this, records showed that the synthetic resin wheels required 75 per cent. less dressing, although the stock removal was increased from 0.001 in. to 0.002 in. per traverse and no tendency to burn occurred. In this operation the average amount of stock removed was between 0.020 in. and 0.030 in. Broadly, approximately 60 per cent. saving in time resulted, superior and more uniform finish with no burns was obtained and greatly increased wheel life was secured.

For the successful use of the synthetic resin wheels, it is important to choose the proper coolant for both cylindrical and

In general, inexperienced operators are employed, who develop their own techniques. Consequently, with vitrified wheels the finished cutters had deep grain scratches on the tooth faces. Some were burned and the ultimate result was fairly high rejections. The advantages of the synthetic resin-bonded wheels already enumerated saved at least 25 per cent. in all-round effort on these regashing operations. As many as 51 cutters have been completed with one synthetic resin wheel. The average is 43, against 8 to 10 using vitrified wheels, i.e., 400-500 per cent. greater wheel life. The average thickness of material removed in a single pass is .005-.008 in.

Tooth forming or back-off grinding is illustrated in Fig. 16, this following the regashing, and is performed on the same machine using a formed wheel of the same width as the tooth to be ground. The



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vitrified wheels gave satisfaction and it required some trials with the synthetic resin wheels to develop one that improved the operation. Ultimately the average number of cutters produced per wheel increased 50 per cent.

On finish grinding, vitrified cup wheels are used on tool and cutter-grinding machines when grinding milling cutters on the land. This is shown in Fig. 17. Grit sizes of 46 to 60 were used for rough and finish grinding without much attention to quality of finish on the cutting edge of each tooth. Some attention had been given to superfinishing of cutting tools using very fine grain of 280-320, in this case shellac or synthetic resin bonded. This entailed an extra-painstaking operation and an experienced operator, and was of limited application.

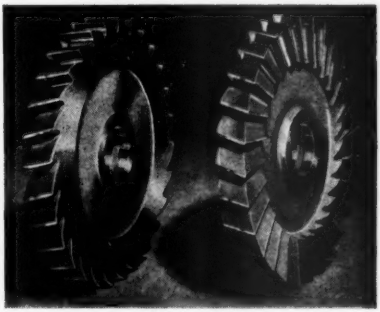


Fig. 23.—Right and left-hand side mills used in test No. 4.

Further work on the synthetic resin-bonded wheels by Cutting Tools and Gauges, Ltd., resulted in their producing hone-finished cutters regularly in one operation with lower cost and improvement in life.

Apart from physical and visual examination and shop trials, comparison of synthetic resin and vitrified wheels was also made by means of profilometer readings. Fig. 18 shows one of these records, indicating clearly the depth of scratches at the cutting edge when a vitrified wheel is used. The record shows variation from peak to peak to be greater than 50 micro-ins.

Fig. 19 is a typical record for a synthetic resin-bonded cutter. The markedly greater uniformity of the cutting edge is very apparent except for teeth Nos. 1 and 7, this indicating careless operating. Variation from peak to peak is less than 3 micro-ins. Apart from the extra cost of synthetic resin-bonded wheels already mentioned, there is no extra cost attached to the grinding and sharpening operations. In fact, there is an overall saving due to the various features elaborated in the foregoing.

The finish grind now standardized by Cutting Tools and Gauges, Ltd., in their reclaiming plant, is as follows:—

Total average stock removal...	0.020 in.
Rough cut ...	0.002 to 0.004 in.
Intermediate cut	0.001 to 0.002 in.
Finish cut ...	0.00025 to 0.0005 in.
Average run-out on finish grind	0.0003 to 0.0005 in.

It is claimed that the overall saving, using resinoid cup wheels, is 25 per cent., in addition to the advantages already cited. It is, of course, important to select the proper grain and grade of synthetic resin wheel suited to the particular tool and to the cutter - grinding machine. Machine speed is also important. Minimum spindle speed should be 5,000 r.p.m. or 5,500 s.f.p.m. Lower speeds are neither satisfactory nor economic for finish grinding. The flaring cup wheel found most satisfactory at these speeds is 4-3 × 2 × 1¼ in. (⅜-in. rim × ⅜-in. back) Alu-Resinoid 60-2-AV-4, or a combination grain 60/80-2AV-4. Regular No. 2 aluminium-oxide grain has been found best suited for combining with a resinoid bond. The special, or white, aluminium oxide has a tendency to break down much faster than the bond, with consequent higher wheel mortality. All Canadian wheel manufacturers, as well as the Carborundum Co. and the Norton Co. in America, are familiar with this type of development. As a guide, a comparison of wheels is given in the attached Table

No. 1 for different manufacturers products.

Regarding dressing, cup wheels should be dressed with a diamond and never with an abrasive stick. The inside wall of the cup should be recessed $\frac{3}{8}$ in. and the spindle head should be offset 30 degrees to do this. To face the wheel, the spindle head should be offset 1 degree opposite the recess angle and then the grinding face dressed to $\frac{3}{16}$ in. wide. The head angle should not be disturbed until after face dressing.

The quality of finish obtained is determined by the technique employed in grinding any cutter. On the intermediate and finish cut the work should be traversed over the stone quickly and returned slowly and steadily. This ensures minimum depth of grain scratch and a polished surface.

Barber-Colman or Ace grinders are also used for tooth-face grinding. An Alu-Resinoid B face wheel is used, grain No. 60 or 80 2-AV-4. For a 7-in.-diameter wheel, machine speed is 4,000 r.p.m. or 7,500 s.f.p.m. If the wheel is reduced to 5-in. diameter, the speed should be increased to 5,500 r.p.m.

Some results from practice in industry can be briefly recorded as follow:—

(a) Milling cutter on breech block, 212-250 per cent. improvement.

(b) Cutter on stainless steel for turbine blades, 47 per cent improvement.

(c) Cutter on machine steel with weld flash, six-seven components improved to 18 components.

(d) Right- and left-hand side mills, grinding after regashing, increase of 65 per cent. per grind.

These results refer to the improvement in the number of components produced using synthetic resin wheels compared with vitrified wheels. The other figures, namely 19, 20, 21, 22, refer to these trials.

Again, in this application of synthetic resins, it will be seen that no specious claims are made, but statements of fact are given in relation to performance. The development is one resulting from wartime conditions forcing the need for increased production. The statements made indicate the use of synthetic resin bonded grinding wheels for specific purposes, wheels of carefully chosen grain and grade, used on tough machining jobs requiring precision accuracy.

TABLE No. 1

Corresponding Canadian and Carborundum Co. Wheel Specifications

Finish Grind-flaring Cup

Lion*

$4/3 \times 2\frac{1}{2} \times 1\frac{1}{4}$

60/80-2-AV-4

Carborundum

$4/3 \times 2\frac{1}{2} \times 1\frac{1}{4}$

61RL-12-K12R-7A

Regashing Dominion†

$10 \times \frac{3}{8} \times 1\frac{1}{4}$

361-J.K.B.

Carborundum

$10 \times \frac{3}{8} \times 1\frac{1}{4}$

361RL-10-K10R-8AF

Back-off or Tooth-forming Dominion†

$10 \times \frac{3}{4} \times 1\frac{1}{2}$

363 I.K.B.

Carborundum

$10 \times \frac{3}{4} \times 1\frac{1}{2}$

363R-12-K12R-9A and

363 RL-12-K12R-9A

Tooth Face-finishing Lion

$10 \times \frac{1}{4} \times 1\frac{1}{4}$

80-2-AV-4

Carborundum

$10 \times \frac{1}{4} \times 1\frac{1}{4}$

80RL-12-K12R-3A

Gash Stagger Tooth Cutters

Carborundum

$10 \times \frac{3}{8} \times 1\frac{1}{4}$

80RL-12-K12R-5A

Surface Grinding

(Abrasive Machine-reciprocating)

Carborundum

$10 \times \frac{3}{4} \times 3$

40S-12-K12R-9A

Cylindrical Grinding (Tool Room)

Carborundum

12 to 20-in. diameter

60RI-10-K10R-5AF

Surface Grinding (Arter Rotary Machine)

Carborundum

$14 \times 1 \times 5$

415-12-K12R-8

* Product of Lion Grinding Wheels, Ltd.

† Product of Dominion Abrasive Wheels Co., Ltd.

PRODUCTION NEWS

Raw Materials, New Plant, Works Organization, Control Apparatus, Research, Personal and Trade Notes

"DIAPLASTICS" WELDING TORCH.—Readers will remember the excellent article in this journal on the welding of thermoplastics by Dr. H. P. Zade. One of the most satisfactory methods is that employing a hot gas welding technique, essentially similar to the gas welding of metals. A welding torch is employed which, however, does not make use of an open flame for the welding operation but employs a jet of heated gas instead. A filler rod is used, which in most cases will be very similar in its composition to the parent material to be welded. The jet of welding gas is heated whilst passing through a stainless steel spiral, which in turn is heated by a gas flame or by electrical resistance elements.

The "Diaplastics" welding torch employs gas for heating and has the

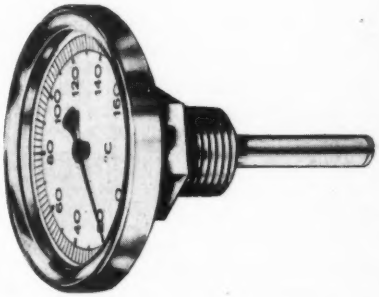
following features:—Weight, 2 lb. 1 oz.; sizes: length, 17 ins.; diameter, 2 ins.; shield diameter, $3\frac{1}{2}$ ins.; nozzle sizes: $\frac{1}{16}$ in., 3-32 in., $\frac{1}{8}$ in. Spare parts are supplied.

The following gases can be used for heating:—Coal gas, town gas, propane, acetylene, mixed with compressed air or oxygen.

The following gases can be used for welding:—Nitrogen, carbon dioxide, oxygen, according to the material to be welded.

The torch is marketed by Diaplastics, Ltd. (proprietors: Arc Manufacturing Co.), 52A, Goldhawk Road, London, W.12.

ECONOMY WITH THERMOMETERS.—Under many industrial and other conditions the annual cost of thermometers or temperature gauges is apt to be somewhat excessive, and the matter has become serious to-day because of the difficulties of replacement. The ordinary mercury-in-glass thermometer has, of course, the inherent disadvantage of being very easily broken, not only by accident, but also because of vibration and normal mechanical shock.



The very small column of mercury also is apt to give trouble because of "sticking" or breaking of the thread. Reading of most mercury thermometers in addition is often difficult. Under the present generally difficult conditions the advantages of the range of bi-metallic dial thermometers made by the British Rototherm Co., Ltd., of London (Merton Abbey, S.W.19), are more important than ever because the maintenance costs and breakage are negligible, since the only glass involved is the thick section in front of the dial.

A wide range of these dial thermometers is available, in three standard types, co-axial, vertical, and flange, each having a metal stem and a metal dial, with a plated bezel like a small clock or pressure gauge, with the pointer moving over a graduated temperature scale which can be easily read from a considerable distance. Each standard model also has one of three sizes of dial, $2\frac{1}{2}$ ins., 4 ins., or 7 ins., with also two standard stem diameters, $\frac{5}{8}$ in. and $\frac{5}{16}$ in., the stem being made to a length to suit the application.

All these models have a die cast bezel, whilst the thick plate glass of the dial is clamped between gaskets and can be

rendered gas, oil, and water-tight, whilst both the stems are of heavy gauge tubing, and the head of the instrument containing the dial is of either a casting or hot stamping.

Standard dials are available giving 15 temperature ranges, that is a low temperature group with a series of graduations from 20 degrees F. to 500 degrees F. having 10 different dials, and a high temperature group with a series of five dials over 500 degrees F. and up to 1,000 degrees F. In addition there is a wide variety of special "Rototherm" designs available for insertion in pipe lines, for taking the temperatures of the surface of pipes or cylinders, for refrigerators, for tanks, and for plastic mixtures. It will be remembered that the basic principle of these instruments is the use of a small bi-metal multi-helical coil contained in the stem, the expansion or contraction of this coil being proportional to the temperature, the movement being transmitted by a light connecting shaft to the dial pointer in the head in the case of the co-axial instruments by direct connection without the use of a gearbox.

"ACTOGRAP" ELECTRIC PEN.—Lorant and Co., of London, S.E.20, informs us that they have issued a new type, "Actograp" No. 2. As is well known, the "electric pen" is widely used in the engineering industries for writing, marking, etching and engraving all types of metal tools, drills, gauges, instruments for production numbering or identification. The No. 2 instrument is a heavy duty one, can "write" extremely fine lines as well as thick ones and operates on 2-4 volts only.

NEW GLYCOL.—Carbide and Carbon Chemicals Corporation, of New York, has put on the market a new glycol, ethylhexanediol. It is high boiling (243 degrees C.), non-volatile and colourless, and is stated to be a promising intermediate for the production of plastics and plasticizers. The same company make a new amine, methyldiethanolamine which is a useful emulsifying agent. For example, it is miscible in both water and benzene.

NEW BRITISH FIBRE.—What is claimed to be the world's strongest fibre is announced by British Celanese, Ltd. It is produced under the trade name of "Fortisan," and is stated to be produced from the same basis as the world-famous "Celanese," presumably cellulose acetate. The material has not yet reached the civilian public, since all production has been devoted to the Services. Its main application is the making of parachutes which carry big loads and which require the minimum of bulk and power for its own transport. Fortisan is also employed in the manufacture of the lines suspending the loads, as well as for barrage balloons. In peace-time it will be applied both for civilian textiles and for the electrical industry, which is taking an interest in its development.

PRODUCTION BULLETIN.—The October issue of the Bulletin, published by the Ministry of Labour and National Service, contains many interesting and novel items for the management and technical development of factories. Among them we note the following: "Quality Control by Limit Gauging," "Quality Control Panel," "Stretch Forming," "Controlling the Plan in the Shop," and "Reclaiming Cracked Castings."

ERINOID, LTD.—The directors recommend a dividend of 10 per cent. less tax on the ordinary stock. The net profit for the year ended July 31, 1944, was £16,802, against £15,974. It is proposed to increase the capital from £330,000 to £750,000 by the creation of 420,000 £1 shares. No immediate issue is contemplated.

PERSONAL

MR. B. S. McLELLAN has been appointed Director of the Scottish Seaweed Research Association. It is interesting to note that seaweed has been suggested for the production of certain types of plastics so that, no doubt, this problem will be examined by the Association.

MR. R. M. S. MORRISON has been appointed sales manager of Scottish Plastics, Ltd. He will operate from that company's offices and showrooms at 89-91, Bothwell Street, Glasgow.

WING COMMANDER T. STANHOPE SPRIGG has been appointed Managing Editor of THE AEROPLANE and associated aeronautical publications.

The new Managing Editor of THE AEROPLANE has been closely associated with British aviation for the past 19 years in his capacity as editor and publisher of aeronautical journals.

From 1941 to 1944 he was Senior Public Relations Officer, Fighter Command, serving on the staffs of two successive Commanders-in-Chief, Air Chief Marshals Sir Sholto Douglas and Sir Trafford Leigh-Mallory.

Planned Mould Maintenance Service Aids Economical Production

Part VII

By W. M. HALLIDAY

Continuing last month's study of the preferred types of design of injection mould component members to ensure effective trouble-free operation

Sprue Bush Construction

MOULDING operations are greatly facilitated if the mould is equipped with a properly designed and constructed sprue channel. One of the chief considerations to be borne in mind by both designer and engineer is the provision of means for drawing free the solidified plastic contained in the sprue passage at the end of each injection "shot." As most moulders will appreciate, lodging plastic material within the sprue channel is one of the most troublesome operating snags, as it may be the cause of repeated production stoppages whilst the adhering material is being cleared by the operator. As is well known in difficult and serious cases, the complete mould may have to be removed from the machine platens in order to clear out the sprue channel.

Some mould makers adopt the practice of cutting the tapered sprue channel direct into the stationary mould block. Several substantial disadvantages are associated with this practice, however. Thus the machining of the tapered hole in the front block may offer difficulties, and, in any case, is apt to be protracted, since the block must be set up in the lathe specially for this operation. Secondly, this hole will have to be polished out very thoroughly after the block has been hardened; it should be ground preferably so as to remove all concentric tooling rings and marks, which, however slight, may cause extra sticking when pulling out the sprue. Restoration of worn sprue-hole surfaces will also present some difficulties, and may even lead to considerable expense.

Because of these and other less important reasons many mould engineers prefer to use a sprue bush rather than cut straight into the mould block.

In Fig. 10 is shown a partial sectioned view of a front mould block and its shoe as fitted with a very commonly used kind of sprue bushing. The sprue bush in this case extends only through the front mould shoe, as shown. It is shaped at its outer end so as to seat upon the semi-spherical tip of injecting nozzle of the machine. It is flanged at this end to

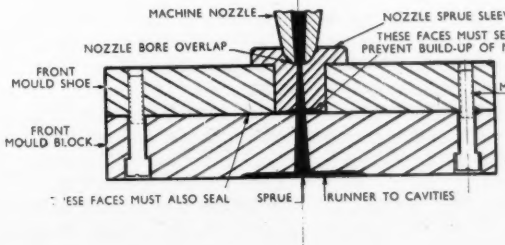


Fig. 10.

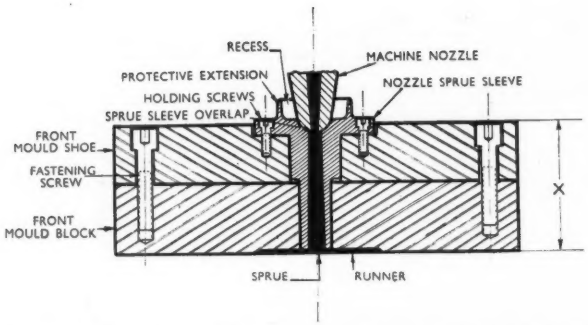


Fig. 11.

bear against the rear face of the shoe. The plain cylindrical shank of the bush is a press fit within the parallel bored hole in the shoe.

Several snags may arise in connection with this construction when in production. These are:—

(1) Should the front mould shoe become distorted or fail for any reason to bed down closely upon the face of the mould block, a gap will be left around the end of the sprue bush, which space will immediately be filled up with material at the next shot. This is indicated in the illustration by heavy black shading. Before the waste sprue can be pulled out this built-up material must be severed, which will entail additional strain both upon the mould components and the pull-out rod and machine members.

(2) It will also be noted that the diameter of the opening in the nozzle tip is larger than that of the entrance to the sprue bush. This will mean that there is a plastic ring of material which will be broken off and pulled through the smaller opening of the sprue bushing. Here, again, some difficulty will be experienced in operating the sprue pull-out mechanism.

(3) Because the nozzle opening is larger than the entrance to the bore of the sprue bush, any misalignment of the nozzle within its sprue bush seating may cause a restriction of the sprue channel, which will result in insufficient feed of material to the mould cavities.

(4) Since the sprue bush does not pass farther than the juncture of the shoe and mould block, even though these two members fit together closely, some tiny crack will be left, which will fill with material.

(5) Some danger exists of surplus material being ejected out of the seating between the nozzle and bush due to imperfect sealing. Material tends to build up at this point, and, in spite of periodical clearances, accumulations do sometimes arise which hold off the nozzle at one point and allow an escape of a fine stream of plastic, to the danger of the operator.

From this list of disadvantages it will be appreciated that this design is defective because of the extreme difficulty in ensuring a close seal between the shoe and mould-block faces, as this is the terminating point of sprue bushing and the degree of nozzle bore overlap.

A very much improved and preferred type of sprue bush construction is illustrated in Fig. 11, this being free from the above drawbacks.

Referring to this sectioned cut of the mould shoe and front block, it will be seen that the sprue bush is extended so as to pass through both mould members right up to the parting-line surface, or rather almost to this point, it coming flush with the bottom surface of runner spacing, as is clearly shown. The shank of the bushing is made of two diameters, the larger one being a press fit into the plain bored hole in the mould shoe, and a

close push fit within the smaller hole bored on the same centres through the front block. The rear face of the shoe member is recessed out to a larger diameter for a short depth in order to house the flanged head of the bush. A number of screws, of the socket-head or cheese-head type, pass through this flange and into tapped holes in the shoe in order to obtain positive retention of the bush against any outward thrust which may arise. It will also be seen that the portion fitted into the shoe is slightly shorter in length than width of this member, so that there is no danger of bearing down on to the mating face of the mould block.

The flanged end of the bushing is extended in the manner indicated, this being a hollow beading whose inner bore diameter is considerably larger than the outside diameter of the machine nozzle, the end of which it encloses. The base of this extension is shaped to form the semi-spherical seating needed for mating up with the nozzle tip.

The diameter of sprue bush bore at the point of contact with the machine nozzle is made larger than the diameter of the hole at outlet of the latter member. This is shown in an exaggerated degree for the purposes of illustration only. In practice, if the difference in these two diameters is made about 1/32nd in., it will be found sufficient.

Readers will readily appreciate the way in which this construction avoids the snags contained in the previous design. As the sprue bushing extends through both shoe and block, practically to the mould parting line, no material can build up between them to cause trouble in pulling out the waste sprue material. As the nozzle bore is slightly smaller than that of the nozzle, any slight misalignment of nozzle on its seat will not cause a restricted entry for the incoming material. The holding screws through the bush flange very effectively prevent any push back of the bush, whilst the protective flanged portion around the nozzle prevents any escaping material from shooting out along a line likely to prove hurtful to the operator. It will be driven back almost parallel with the nozzle itself, instead of nearly at right angles to it as in former construction.

In the method of fitting this type of bush it may sometimes be advisable to make the portion passing through the shoe and front block long enough to pass right to the parting-line face, that is equal to distance X minus the depth of recess for head of bush. Then with the bush fitted, the runners could be cut, passing clean through the end of the bush into its bore.

This type of sprue bush is recommended as one entailing far less maintenance inspection and servicing than the former type already commented upon.

There are a few other important general provisions relating to sprues and sprue bushings upon which some guidance might usefully be given.

Regarding the degree of taper of the bore of the sprue bush. On the whole it is wiser to err on the large size with the taper rather than with one too small. For this reason. If a very slow angle is made troubles are very apt to arise when pulling out the material, especially so if the surface of the sprue bore is not very highly polished and entirely free from all concentric turning-tool marks, etc. Good working practice inclines to a taper of 5 degrees included angle. A taper less than about 3 degrees will give unsatisfactory results. A larger degree of taper may cause wastage of material, especially if the sprue bush is very long.

Still further to ensure against lodgment of material in the sprue bush, they should always be made of good-grade steel, carefully hardened and ground, with lapped bores. This will not only enable a very smooth and glass-hard surface being secured, but also safeguard against damage and bruises if an operator should carelessly use a brass rod or steel pin to drive out a lodging piece of plastic. Care should be taken to see that an excessive degree of hardness is not imparted to the bush, at its seating

end at any rate, lest the great pressures arising from the nozzle clamping down cause cracking of the bush.

The task of installing replacement bushes is also considerably simplified by employing a design of this kind, and, in fact, where steps are taken by the mould designer to confine as far as possible mould block and shoe thicknesses, it will often be possible to contrive a small range of sprue bush lengths which will be applicable to a large number and variety of mould designs. Thus in this manner the task of stocking standard sprue bushings will be greatly eased, and the question of refitting a mould with a new sprue channel becomes quickly settled.

Another direction in which such a standardization of sprue bush sizes will assist is in enabling the tool-room to make up standard reamers and finishing tools generally for making the proper angle and obtaining a lapped polished surface thereon after hardening, which is otherwise impossible when sizes are not standardized. Indirectly, this provision will greatly convenience those charged with mould maintenance.

Ejector Rod Assemblies and Designs

Although injection type of moulds vary very considerably in details of their design, construction and arrangement, there are certain component parts which are practically always employed upon every mould assembly, large or small, intricate or simple. These are the sprue bushing, dowels, and ejector rods and ejector rail. Little variation in these parts need be necessary over many different mould constructions, and they are capable of being adapted in respect to their sizes and types as to permit of simple standardization. Where this is undertaken considerable economies can be effected both in the drawing office as well as the tool-room and stock-room.

Such a course will be especially applicable to the question of ejector provision, as these parts are used in large numbers, and often demand replacement because of their proneness to a number of operating snags.

Ejector mechanisms should be installed on every mould so as to afford means for the safe, smooth and rapid removal of the finished moulding or mouldings after each "shot" of the injection plunger.

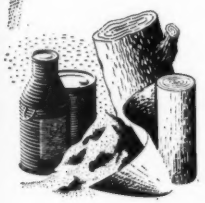
Their chief function is to press forward the moulded part so as to bring it clear of the cavity area and any fixed core blocks contained therein. Usually they are attached to a plate or rail, which latter member is suitably guided so as to slide along a given track for specified distances. Their movement is carefully controlled by the rail, and each ejector pin affixed thereto is also generally constrained to slide within a hole formed in the mould block. The opposite end of each rod is made to terminate in the base of the mould cavity or upon the runner. An adequate number of ejectors should be provided for each cavity, so as to ensure very uniform contact and movement with the finished moulding to be ejected. Care should also be taken to avoid arranging the ejectors in such a manner that their contacting pressure upon the moulding causes the latter to move out of the cavity area on the cross. If this should occur the component will probably hang-up in the cavity or upon a core, resulting not only in a faulty article but, as likely as not, some damage to the ejector rods themselves.

The contacting end of all ejectors should be of adequate area to prevent punching through the walls of the moulding, as will happen if the head is made very small in diameter. Generally, a few large diameter ejector pins will be more satisfactory in use than a much greater number of small ones, although where limitations exist governing the diameter of pin permissible, a larger quantity of small pins may have to be employed.

Ejector pins are normally made from standard gauge sizes of highly polished silver-steel rod or ground high-speed steel rod. The working end of the ejector rod —that is, the one contacting with the moulded article—should always be well hardened for a good distance back, because pins left in the soft condition are very apt to seize up in their guide

"PLASTICS are a BIND"

. . . AS THE R.A.F. WOULD SAY



BEETLE RESINS, for instance. They bind together lots of things—sawdust, fabric, wood, pigments and so on. Sometimes they make moulded articles like electric switches, sometimes they make cardboard weatherproof and tough. They may bind a Mosquito aircraft together or appear as the bond in laminated sheets. And the bind is permanent—once the operation is performed heat or damp has no effect. There's a great future for Beetle bonding —are you interested in the future?

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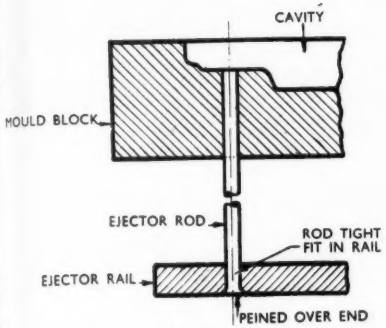

Fig. 12.

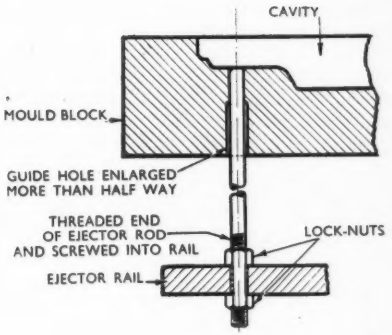

Fig. 13.

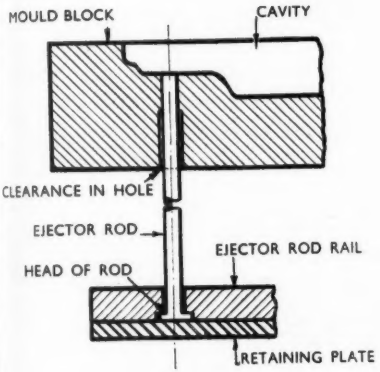

Fig. 14.

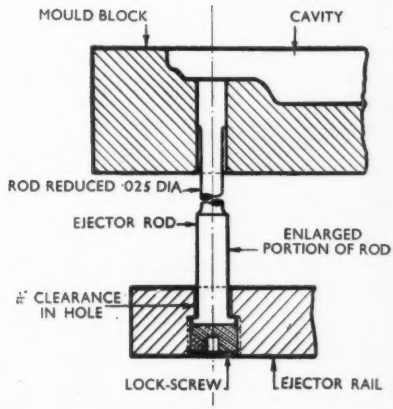

Fig. 15.

holes in the mould block. Some mushrooming effect is also likely to occur at the extreme end, due to the continual pressure against the walls of the moulded articles ejected. This will also tend to hasten seizure or tightness in the sliding movement.

The four partial sectioned views shown in Figs. 12 to 15 illustrate a number of very common methods of ejector-pin assembly, with special reference to the means of attachment to the ejector rail.

Fig. 12 shows, perhaps, one of the most widely used types, but it is one not to be recommended in spite of its simplicity and low installation cost. The ejector pin is of small diameter and made perfectly plain throughout its length. It is made a press fit within the ejector plate, and a portion peined over to form a head on the back edge of the rail, as shown.

Several snags may be cited against the satisfactory use of such a method of fixture. In the first place, there is little resistance to the forward pushing pressure of the pin upon the moulded piece, with the result that it may easily be forced backwards out of the correct position in the rail. The riveted head is actually on the wrong side to be of assistance in withstanding such pressure. Secondly, no relief is provided for the sliding movement of the rod in the hole in the mould

block, with resultant danger of stiffened working or eventual seizure. Thirdly, because of the thinness of the ejector rail, it is extremely doubtful whether the ejector rod can be fitted and riveted over and maintained perfectly square with the rail. Should the peening operation force over the pin unequal strain will be imposed on the rail, whose movement will be accordingly stiffened. In cases where a rail is fitted with a number of such rods each out of square in some degree, a considerable binding action may result.

Fig. 13 shows a slightly improved method to the foregoing. The end portion of the ejector rod to be fitted into the rail is threaded for a sufficient distance to receive a pair of lock-nuts. The hole in the rail is also tapped to take the pin, and a nut is secured each side, so as to lock the pin in place. Also, the guide hole in the mould block is enlarged in diameter for a distance, as shown, so as to give a slight clearance to the pin.

The chief advantage possessed by this type is that it allows an adjustment of the ejector pin, which is simply secured by releasing the nuts and moving the pin in the appropriate direction. But all the disadvantages noted in respect of the type shown in Fig. 13 are present here also. It is difficult to ensure a perfectly square location of the pin by reliance solely upon a threaded contact between it and the rail.

Another serious drawback associated with both these designs is that they are rigidly fixed to the ejector rail.

Adjustment for Temperature Fluctuations

During production there will always be a very considerable difference in the temperature of the mould block and that of the ejector rail, which means that these two members will have wide variations in rate and extent of their expansion. Where the ejector pins are rigidly secured to their rail, as in the two instances already quoted, they will tend to expand less than the mould block, with the result that each pin will bear on one side of its guide hole with greater pressure than the other. This may cause each pin to become slightly distorted or bent, or may result in stiffened working and seizure of the pin in its hole.

Easement of such tendencies is commonly effected either by extending the length of pins or by opening out their guide holes in the mould block, so as to spread any distortion likely to arise over a greater length of pin. But increased pin length may give rise to other troubles, and usually where such measures are adopted there is to be noted a slight reduction in production, as the mould must be operated somewhat slower.

The methods shown in the two constructions in Figs. 14 and 15 are much to be preferred as being considerably sounder and more reliable in service, and especially because they provide a simple way of overcoming the aforementioned troubles due to unequal expansion.

Dealing first with the form shown in Fig. 14, it will be seen that the ejector pin is provided with a head portion at the ejector rail end. The rail itself is drilled slightly clearance size, approximately 1/64 in. larger than the diameter of the rod. The lower end of the hole is recessed to receive the head. The rod is prevented from pushing back out of the rail by the thin retaining plate securely fastened to the rail after the ejector pins have been placed in position.

With this design, should it become necessary to adjust the setting of the pin, the retaining plate may be removed and a slight amount shaved off the underside of the pin head. Shimstock may then be applied to the appropriate side of its head, so as to move the pin outwards or backwards relative to the rail. The clearance provided in the hole in the rail enables any slight misalignment or distortion due to expansion, etc., being readily taken up without causing permanent damage to the pin or stiffened working in its guide hole.

The method illustrated in Fig. 15 is also one which will prove satisfactory in service, and should give prolonged operation without maintenance attention, save a mere inspection for effects of wear or an occasional adjustment.

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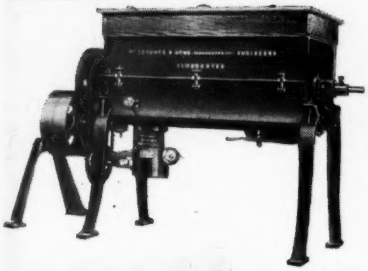

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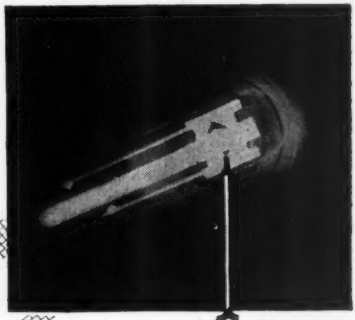
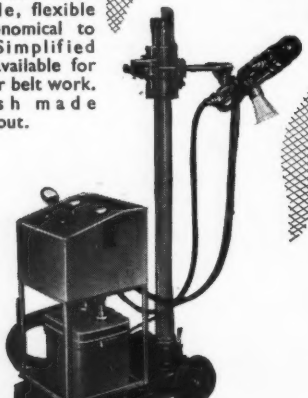


Radiograph of moulded assembly showing incorrect location of metal insert.



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It will be noted that on the other designs the guiding hole in the mould is opened out for a certain portion of its length to afford working clearance to the pin. In this construction, however, the pin itself is reduced slightly in diameter on its middle portion, whilst the guide hole in the block is left perfectly parallel. The advantage of this is to be found in the greater ease by which an assembled rail may be inserted into the mould block. This is especially convenient in the case of a multi-impression mould, where the ejector rail will have a large number of pins. Getting each one properly into its guide hole is more easily accomplished when the hole is one diameter clean through rather than with a stepping down to working diameter half-way up its length. It also avoids the danger of ejector pins becoming jammed, as will occur in the other constructions if the rail is inadvertently withdrawn too far back, allowing the pins to pass into the clearance portion.

Fixing of Rod

The method of fixture of the rod within the ejector rail is also very useful. The rail has a clearance hole, in which the shank of the rod is free to float a slight amount. The rod is headed, and resides deep within a counterbored portion of the hole in the rail. This counterbore is internally threaded to receive the socket head lock screw, which can be screwed down to bear upon the head of the rod. The rail is made much thicker, as shown, in order to accommodate this screw assembly.

Another useful feature which will assist in avoiding numerous operating troubles, such as deflecting rods, bending and fracture, is the provision of an enlarged shank portion to the ejector pin. This may be made larger than the contacting end if the pins have to withstand considerable pressures in removing the moulding.

Ejector pins should always be circular in cross section and kept within the range of standard diameters as far as possible, as these features will not only promote more inexpensive mould manufacture but also greatly facilitate renewals in the case of worn pins.

Flat, rectangular or square-shaped ejectors should never be employed on account of the difficulty in suitably machining these and their guide holes, and the extreme difficulty which will be experienced when having to make good, or adjust for wear, after the mould has been in use for some time.

Where extremely long runs are required from a mould it will be advisable and profitable to arrange for all ejector pins to slide within specially hard guide bushes secured within the mould block, rather than within plain holes in the block itself. Such bushes can be speedily and cheaply replaced in the case of excessive wear or other damage caused during operation. Means should also be provided for supplying lubricant in some form to such pins and their guide holes.

In those cases where the ejector pin is threaded and screwed into its rail, standard thread sizes should be employed, and care taken in spacing the location of such pins on the rail to allow for the lock-nuts which must be provided.

The usual maintenance overseeing demanded by ejector mechanisms covers, first, the degree of security and location within the rail; next the smoothness of sliding action of the pin within the mould block; to observe the deflecting effects produced on the pin by reason of expansion; to inspect the contact end for presence of burrs, mushroom or wear. It will also be necessary to test the rail itself for freedom of movement throughout the full distance of its travel, also to ensure it is adequately and accurately guided, so that the rail moves at uniform rates at each end, and squarely with parting-line face of the moulds. Given a sound design and adequate provisions for lubrication, adjustment and resistance to normal wear, such mechanisms can be arranged so as to give prolonged and relatively trouble-free service. With ordinary operating care there should in all such installations be an absence of major breakdowns due to fractured or seized ejector rods.

Conclusion

In the preceding pages attention has been directed towards some of the main features of injection mould design and construction with particular reference as to the manner in which these various aspects of design, etc., may be modified or adapted so as to incur the least amount of maintenance supervision, or risk of serious breakdown.

Of necessity many very interesting points have had to be omitted, as, for example, complicated coring layouts, for producing a large number of cored holes in the finished moulding simultaneously; the employment of geared or cam-operated core withdrawal mechanisms, many of which involve very varied and indeed ingenious constructions possessing interesting features for the consideration of the maintenance toolmaker.

In all such instances where elaborate or intricate mechanisms for operating cores, or other mould members are contemplated close attention should be given to the problems likely to arise in effectively maintaining them throughout prolonged production runs. It is often easy to design and install apparatus capable of performing certain motions or functions for a short period, but often difficult so to fashion a mechanism which will function for long periods without attention and throughout maintain a close degree of accuracy, smoothness and reliability. Unless a mechanism capable of operating in this latter manner is developed then the maintenance engineer will find heavy demands made upon his time and attention to keep the mould or parts of same in reasonably sound working condition.

In leaving consideration of the chief features of injection mould construction it is hoped that enough has been written to indicate the many simple yet effective ways in which the mould engineer and maintenance toolmaker may co-operate in evolving design or constructional factors calculated to give highest degree of efficient operation.

Succeeding sections will be devoted to the study of numerous mould designs for the production of injection mouldings externally or internally threaded portions. Moulds for such purposes very often entail special maintenance difficulties as well as design or manufacturing problems. Typical mould designs will be considered to illustrate advantages or disadvantages with special reference to the retention of accuracy, rapid operation, soundness of finished products, and so on.

The use and care of such thread-forming injection moulds requires perhaps more frequent or regularized inspection, test, cleaning, and overhaul by the maintenance toolmakers than with the types of moulds already dealt with, whilst operator training in the best and safest use of such moulds needs to be very thoroughly undertaken.

Softening of GR-S

The Controller of Chemical Research (Ministry of Supply) has issued a Manufacturers' Memorandum (No. M.9) entitled "The Thermal Softening and Peplisation of GR-S."

When natural rubber is heated in oxygen or air, softening takes place and is increased as time of heat application increases. With GR-S heating in oxygen causes softening by oxidation, but after a period the softening effect is stopped and hardening takes place, due to cyclization. In the report it is suggested that the hardening effect which takes place in the second heating of the synthetic is due also to oxidation.

Various materials and methods believed to accelerate thermal softening were examined in order to obtain correlating data. Among additives examined were phenyl naphthylamine, which is typical of anti-oxidants, benzyl phenyl hydrazone, and iron naphthenate, which is commonly used to produce tacky products from rubber.

The important conclusion arrived at is that big improvement in tack and plasticity of GR-S can only be expected by changes in polymerization. Excessive softening or the use of large amounts of softeners in GR-S leads to impairment of some of the properties of the vulcanizates.

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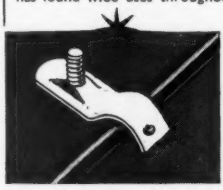

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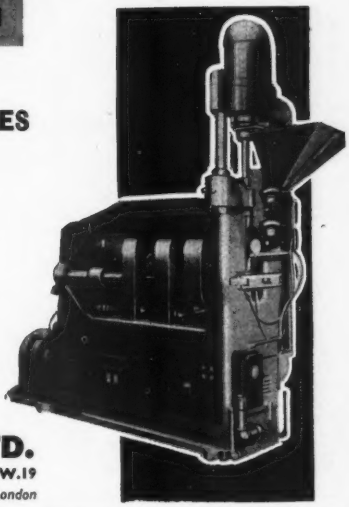

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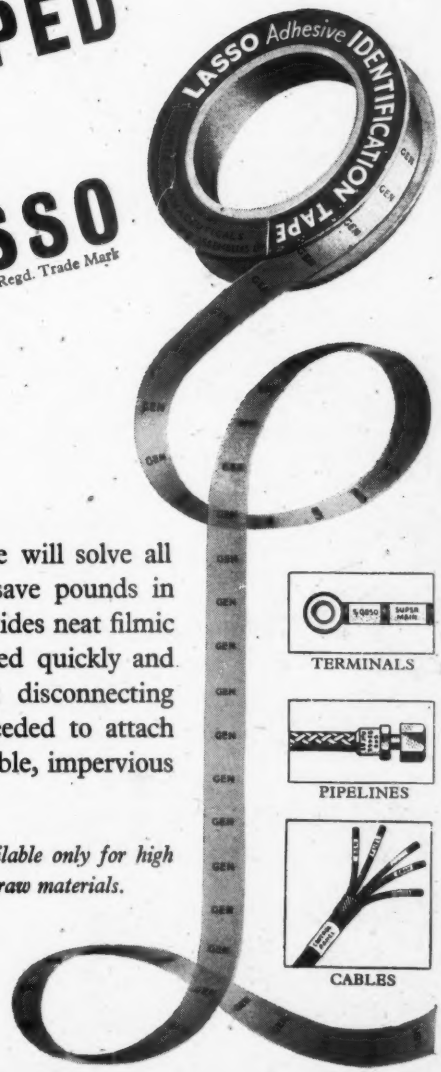

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